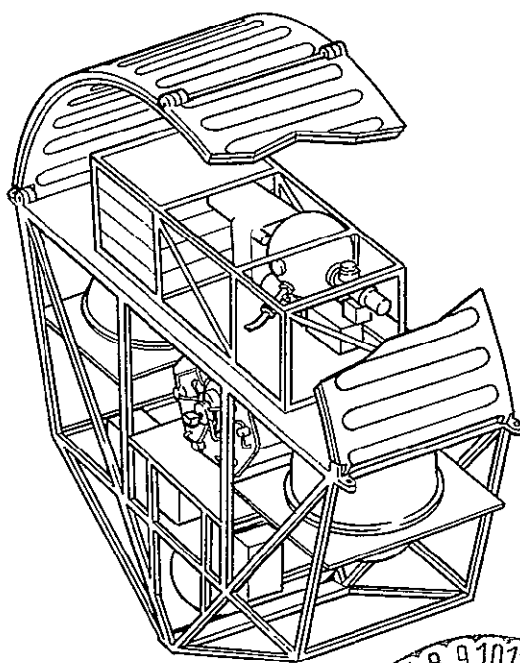


# Automated Space Processing Payloads Study (Contract NAS 8-30741)

## Volume II Book 2 Technical Report Appendices A through E

**Final Report  
BSR 4171**

January 1975



(NASA-CR-120774) AUTOMATED SPACE PROCESSING  
PAYLOADS STUDY. VOLUME 2, BOOK 2:  
TECHNICAL REPORT, APPENDICES A THROUGH E  
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**Aerospace  
Systems Division**

# **Automated Space Processing Payloads Study (Contract NAS 8-30741)**

## **Volume II | Book 2 Technical Report Appendices A through E**

**Final Report  
BSR 4171**

January 1975

Prepared for:

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National Aeronautics and Space Administration  
Marshall Space Flight Center, Alabama 35812

Prepared by:

The Bendix Corporation  
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**Aerospace  
Systems Division**

APPENDIX A  
EXPERIMENT DATA SHEETS

## EXPERIMENT|DESIGNATION B-1

TITLE: Electrophoretic Separation of Cells, Serums, and Proteins

OBJECTIVE: Determine feasibility and evaluate the advantages of methods for electrophoretic separation of biological preparations in space.

## PROCESS STEPS:

| <u>Stationary Column</u>                         | <u>Continuous Flow</u>            |
|--|-----------------------------------|
| 1. Fill with buffer solution.                    | 1. Start buffer flow.             |
| 2. Set power for voltage versus time program.    | 2. Sample injection.              |
| 3. Introduce sample.                             | 3. Sample collection and storage. |
| 4. Sample separation, detection, and collection. | 4. Sample preservation.           |
| (5. Sample analysis.)                            | 5. System purge.                  |
| 6. Sample preservation.                          |                                   |
| 7. System purge.                                 |                                   |

## SPECIAL HARDWARE:

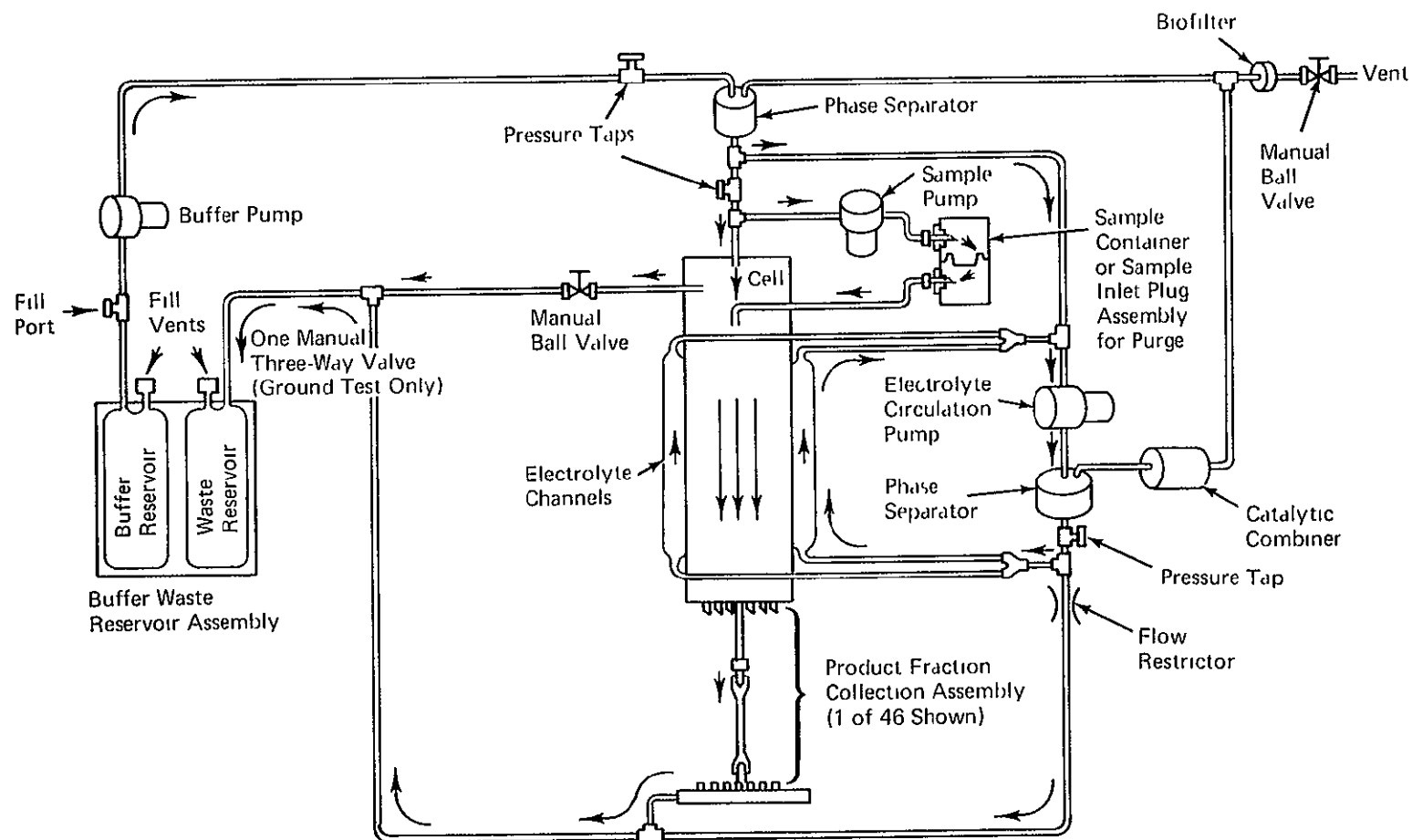
1. Electrophoretic column(s).
2. Sample preservation and storage facilities.
  - (a) Freezing facility.
  - (b) Refrigerated storage.
3. Sample transfer equipment.

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Events.
2. Cell electrode voltage(s).
3. Current in separation column(s).
4. Cell temperature(s).
5. Cell voltage gradient(s).
6. Flow-rate of sample pump.
7. Flow-rate of buffer pump.

See Figure A-1.

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BSR 4171

Figure A-1 ES Fluid Flow Schematics

EXPERIMENT DESIGNATION B-2

TITLE: Growth of Bacterial Cultures

OBJECTIVE: Study growth of bacterial cultures in a zero-gravity condition.

PROCESS STEPS:

Load samples.  
Temperature control over measured time.  
Sample removal and storage.

SPECIAL HARDWARE:

Culture media.  
Biological enclosure.  
Manipulator.

RECORDING AND ANALYSIS REQUIREMENTS

Process parameters.

EXPERIMENT| DESIGNATION B-3

TITLE: Bio-Growth of L-Phase Organisms

OBJECTIVE: Determine growth rate of L-phase organisms under orbital conditions, i.e., possibility of aeration without agitation and absence of liquid head-pressure.

PROCESS STEPS:

Samples would be contained within a controlled biological enclosure. No other process steps are required besides initial transfer of samples to enclosure and removal at end of mission.

SPECIAL HARDWARE:

Biological enclosure.  
Manipulator.

RECORDING AND ANALYSIS REQUIREMENTS:

Process parameters.

EXPERIMENT DESIGNATION B-4

TITLE: Dialysis, including Fermentation

OBJECTIVE: Study fermentation processes in a weightless condition.

PROCESS STEPS:

1. Insert samples.
2. Control process parameters over measured time.
3. Remove and store samples.

SPECIAL HARDWARE:

Fermentation apparatus.  
Manipulator.

RECORDING AND ANALYSIS REQUIREMENTS:

Process parameters.



EXPERIMENT DESIGNATION B-5

TITLE: Lyophilization

OBJECTIVE: Develop techniques of lyophilization (freeze drying) of biological materials in a weightless environment and evaluate how results differ from conventional techniques.

PROCESS STEPS:

1. Insert sample vials.
2. Reduce temperature ( $-10^{\circ}\text{C}$ ).
3. Expose to vacuum.
4. Raise temperature ( $50^{\circ}\text{C}$ ).
5. Stopper sample vials.
6. Remove and store.

SPECIAL HARDWARE:

Biological enclosure.  
Lyophilization apparatus.  
Storage units.  
Manipulator.

RECORDING AND ANALYSIS REQUIREMENTS:

Process conditions (temperature, pressure, and time).

## EXPERIMENT DESIGNATION C-1

(Comparable to M556 Skylab and MA-085 ASTP)

TITLE: Crystal Growth from Vapor (e.g., Cadmium Selenide [CdSe])

RELATED CONTRACT: NAS8-26146

OBJECTIVE: To determine degree of improvement that can be obtained in the perfection and homogeneity of crystals grown by vapor transport under zero g.

## PROCESS:

| <u>Steps</u>                          | <u>Parameters</u>        |
|---------------------------------------|--------------------------|
| 1. Insert capsule.                    |                          |
| 2. Heat material.                     |                          |
| 3. Regulate temperature and gradient. | $\pm 1^{\circ}\text{C}.$ |
| 4. Allow crystal to grow.             | For 2 hours.             |
| 5. Cool.                              | About 8 hours.           |
| 6. Remove and stow capsule.           |                          |

## SPECIAL HARDWARE:

- |                     |       |
|---------------------|-------|
| 1. Special capsule. |       |
| 2. Manipulator.     |       |
| 3. Gas system.      |       |
| 4. Furnace.         | 1 kW. |

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature/pressure/time profiles.
3. Post-mission analysis.
  - (a) Physical properties measurement.
  - (b) X-ray and optical properties measurement.
  - (c) Correlation of properties and process parameters.

## EXPERIMENT DESIGNATION C-2

TITLE: Crystal Growth by Pulling from Containerless Melt (e. g., Silicon)

OBJECTIVE: To grow crystals on seed from levitated molten mass.

## PROCESS:

| <u>Steps</u>                               | <u>Parameters</u>                              |
|--|--|
| 1. Insert material and pressurize chamber. | 50 cm <sup>3</sup> , 1 atmosphere.<br>1,410°C. |
| 2. Melt material.                          |  |
| 3. Levitate material.                      |  |
| 4. Insert seed.                            | 0.6 to 2.5 cm per hr.                          |
| 5. Rotate and withdraw seed.               |  |
| 6. Retrieve and stow crystal.              |  |

## SPECIAL HARDWARE:

|   |       |
|---|-------|
| 1. Manipulator.                             | 3 kW. |
| 2. Furnace heater                           |       |
| 3. Levitation, acoustic or electromagnetic. |       |
| 4. Gas system.                              |       |

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Rotation and withdrawal rates.
3. Temperature and time profile.
4. Post-mission analysis.
  - (a) Physical properties measurement and correlation with processing parameters.
  - (b) Photomicrograph.

## EXPERIMENT DESIGNATION C-3

TITLE: Crystal Growth in Aqueous Solutions and Flux (e.g., Yttrium Iron Garnet)

RELATED CONTRACTS: NAS8-29077, 28098, and 28114.

OBJECTIVE: To grow improved crystals by autonucleation in heated flux.

## PROCESS:

| <u>Steps</u>                         | <u>Parameters</u>  |
|--------------------------------------|--|
| 1. Insert material.                  | 30% solution YIG (1 kg) in PbO-PbF <sub>2</sub> (90-10). |
| 2. Heat material.                    | 1,300°C.   |
| 3. Cool material at programmed rate. | To 1,100° at 1.7°C per hr.                               |
| 4. Quench.                           | To 850°.   |
| 5. Slowly cool.                      | To 250° in 3 hours.                                      |
| 6. Remove crucible and stow.         |  |

## SPECIAL HARDWARE:

|                       |         |
|-----------------------|---------|
| 1. Platinum crucible. |         |
| 2. Manipulator.       |         |
| 3. Furnace.           | 1.3 kW, |
| 4. Gas system.        |         |

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature and time profile.
3. Post-mission analysis.
  - (a) Physical and optical properties measurement.
  - (b) Correlation with process parameters.

## EXPERIMENT DESIGNATION C-4

TITLE: Crystal Growth by Pulling from Molten Zone (e.g., Titanium Dioxide,  $TiO_2$ )

OBJECTIVE: To prepare large single crystals under zero-g; comparison with similar crystals grown on Earth.

## PROCESS:

| <u>Steps</u>  | <u>Parameters</u>    |
|---|----------------------|
| 1. Insert polycrystalline rod (in special cartridge). | 55 cm <sup>3</sup> . |
| 2. Heat rod to melt.                                  | 1, 850°C.            |
| 3. Insert seed.                                       |                      |
| 4. Retract seed.                                      | 1 cm per hr.         |
| 5. Advance rod.                                       | As required.         |
| 6. Cool at programmed rate.                           | 12 hours to 200°C.   |
| 7. Retrieve and stow crystal.                         |                      |

## SPECIAL HARDWARE:

|                       |         |
|-----------------------|---------|
| 1. Alumina cartridge. |         |
| 2. Manipulator.       |         |
| 3. Furnace.           | 1.8 kW. |
| 4. Gas system.        |         |

## RECORDING AND ANALYSIS REQUIREMENT

1. Event times.
2. Temperature and time profile.
3. Post-mission analysis.
  - (a) Physical properties measurement.
  - (b) X-ray and optical properties measurement.
  - (c) Correlation of properties with those of crystals grown on Earth and with process parameters.

EXPERIMENT DESIGNATION C-5

(Comparable to Skylab M560)

TITLE: Sphere Seeding (e. g. , Indium Antimonide, InSb)

OBJECTIVE: To study supercooling mechanisms in growth of a single crystal from containerless melt under zero g.

PROCESS STEPS:

1. Insert material.
2. Heat material.
3. Levitate material.
4. Cool.
5. Insert seed.
6. Retrieve and stow crystal.

SPECIAL HARDWARE:

1. Manipulator.
2. Enclosure.
3. Levitation and induction heating.
4. Cooling system.

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature and time profile.
3. Video or photographic recording
4. Post-mission analysis.

EXPERIMENT DESIGNATION C-6

(Comparable to M563 Skylab)

TITLE: Mixed III-V Crystal Growth (e.g., GaSb)

OBJECTIVE: To determine how zero g affects solidification of binary semiconductors and how properties depend upon composition.

PROCESS STEPS:

1. Insert cartridges and evacuate chamber.
2. Heat sample.
3. Cool.
4. Retrieve and stow sample.

Total time estimate: 42 hours.

SPECIAL HARDWARE:

1. Furnace/enclosure.
2. Manipulator.
3. Vacuum system.

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature/pressure/time profile.
3. Post-mission analysis.
  - (a) Properties measurement.
  - (b) Correlation of properties with process parameters.
  - (c) Photomicrography.

EXPERIMENT DESIGNATION C-7

(Comparable to M562 Skylab)

TITLE: Indium Antimonide Crystals

OBJECTIVE: To produce semiconductor crystals of high structural perfection and to evaluate the effects of zero g on physical properties.

PROCESS STEPS:

1. Insert cartridge and evacuate chamber.
2. Heat sample.
3. Cool.
4. Retrieve and stow sample.

Total Time Estimate: 22 hours.

SPECIAL HARDWARE:

1. Furnace with enclosure.
2. Manipulator.
3. Vacuum system.
4. Cooling system.

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature/pressure/time profile.
3. Post-mission analysis.
  - (a) Physical properties measurement.
  - (b) Correlation with process parameters.
  - (c) Photomicrography.



## EXPERIMENT DESIGNATION G-1

TITLE: Preparation of Conventional Glass (e. g., Silicon Dioxide) by Containerless Method

OBJECTIVE: To evaluate effects of weightless preparation on crystallinity and optical and physical properties of conventional glasses.

## PROCESS:

| <u>Steps</u>                 | <u>Parameters</u>    |
|------------------------------|----------------------|
| 1. Insert sample.            | 10 cm <sup>3</sup> . |
| 2. Heat sample.              | 1,715°C.             |
| 3. Levitate sample.          |                      |
| 4. Stir sample.              |                      |
| 5. Monitor sample.           |                      |
| 6. Cool sample.              |                      |
| 7. Retrieve and stow sample. |                      |

## SPECIAL HARDWARE:

|                             |       |
|-----------------------------|-------|
| 1. Manipulator.             |       |
| 2. Furnace or laser heater. | 2 kW. |
| 3. Levitation, acoustic.    | .     |
| 4. Mixer, acoustic.         |       |
| 5. Gas system.              |       |

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature and time profile.
3. Post-mission analysis.
  - (a) Physical properties measurement.
  - (b) Optical properties measurement.
  - (c) Correlation of measured properties with processing parameters.

EXPERIMENT DESIGNATION G-2

TITLE: Fiber Optics

OBJECTIVE: To produce low-loss glass fibers for use as light pipes.

PROCESS STEPS:

1. Insert preform.
2. Heat preform.
3. Levitate preform.
4. Pressurize chamber.
5. Melt preform.
6. Draw fiber and spool.
7. Stow fiber.

SPECIAL HARDWARE:

1. Manipulator.
2. Furnace.
3. Levitation.
4. Induction heater.
5. Laser heater.
6. Gas system.

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature/pressure/time profile.
3. Post-mission analysis.
  - (a) Physical (including optical) properties measurement.

EXPERIMENT DESIGNATION G-3

TITLE: Mixing of Conventional Glass

OBJECTIVE: To evaluate a mixing technique for space production of glass.

PROCESS STEPS:

1. Insert sample and pressurize chamber.
2. Heat sample.
3. Mix sample.
4. Cool sample.
5. Retrieve and stow sample.

SPECIAL HARDWARE:

1. Manipulator.
2. Furnace.
3. Mixer.
4. Gas system.

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature/time profile.
3. Post-mission analysis.
  - (a) Physical (including optical) properties measurement.
  - (b) Correlation with process parameters.

EXPERIMENT DESIGNATION G-4

TITLE: Zirconia Glass

OBJECTIVE: To produce  $\text{ZrO}_2$  glasses by levitation in zero g.

TOTAL PROCESS TIME: 2 hours.

PROCESS STEPS:

- |                            |                          |
|----------------------------|--------------------------|
| 1. Insert sample.          | 0.6 in. diameter sphere. |
| 2. Pressurize chamber.     | 1 atmosphere.            |
| 3. Levitate sample.        |                          |
| 4. Melt sample.            | 2,700°C.                 |
| 5. Hold at temperature.    | 5 minutes.               |
| 6. Cool sample.            | 100 minutes.             |
| 7. Remove and stow sample. |                          |

SPECIAL HARDWARE:

- |   |       |
|---|-------|
| 1. Manipulator.                                       |       |
| 2. Furnace enclosure.                                 |       |
| 3. Levitation and mixer, acoustic or electromagnetic. |       |
| 4. Heater, e.g., image furnace.                       | 2 kW. |
| 5. Gas control system.                                |       |

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature/pressure/time profile.
3. Post-mission analysis.
  - (a) Measurement of optical properties.
  - (b) Correlation of measured properties with processing parameters.

EXPERIMENT DESIGNATION G-5

TITLE: Amorphous Solidification

OBJECTIVE: To investigate phenomena affecting glass formation.

PROCESS STEPS:

1. Insert sample.
2. Heat sample and pressurize chamber.
3. Levitate sample.
4. Melt sample.
5. Cool sample.
6. Retrieve and stow pressurize.

SPECIAL HARDWARE:

1. Manipulator.
2. Furnace.
3. Levitation.
4. Induction heater.
5. Gas system.

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature/pressure/time profile.
3. Post-mission analysis.
  - (a) Measurement of physical (including optical) properties.
  - (b) Correlation with process parameters.

## EXPERIMENT DESIGNATION G-6

TITLE: Space Processing of Chalcogenide Glasses (e. g., GeTe)

OBJECTIVE: To investigate elimination of causes of optical inhomogeneity in chalcogenide glasses by processing in zero g.

TOTAL PROCESS TIME: 13 minutes.

## PROCESS:

| <u>Steps</u>                 | <u>Parameters</u>        |
|------------------------------|--------------------------|
| 1. Insert sample.            | 0.8 in. diameter sphere. |
| 2. Pressurize chamber.       | 1 atmosphere.            |
| 3. Heat sample.              | 600°C.                   |
| 4. Levitate sample.          |                          |
| 5. Melt sample.              | 800°C.                   |
| 6. Hold at temperature.      | 4 minutes.               |
| 7. Cool sample.              | 4 minutes.               |
| 8. Retrieve and stow sample. |                          |

## SPECIAL HARDWARE:

|   |       |
|---|-------|
| 1. Manipulator.                                     |       |
| 2. Pre-heater.                                      | 2 kW. |
| 3. Electromagnetic levitation and induction heater. | 2 kW. |
| 4. Gas system.                                      |       |

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature/pressure profile.
3. Post-mission analysis.
  - (a) Physical properties measurement.
  - (b) Optical measurements.

## EXPERIMENT DESIGNATION G-7

TITLE: Preparation of Conventional Glass by Furnace Method (Silicon Dioxide)

OBJECTIVE: To study effects of zero g on conventional glass preparation in crucible.

## PROCESS:

| <u>Steps</u>                       | <u>Parameters</u>                                    |
|------------------------------------|--|
| 1. Insert sample in crucible.      | 200 cm <sup>3</sup> .                                |
| 2. Melt sample.                    | 1,715°C.   |
| 3. Hold at temperature.            | 1 hour.  |
| 4. Cool sample at programmed rate. | Quench to 1,200°C, then<br>at 0.5° per min to 200°C. |
| 5. Retrieve and stow sample.       |  |

## SPECIAL HARDWARE:

|                      |         |
|----------------------|---------|
| 1. Special crucible. |         |
| 2. Furnace.          | 1.7 kW. |
| 3. Manipulator.      |         |
| 4. Gas system.       |         |

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature/pressure/time profile.
3. Post-mission analysis.
  - (a) Optical and physical properties measurement.
  - (b) Correlation with process parameters.

## EXPERIMENT DESIGNATION G-8

TITLE: Alumina Glass

OBJECTIVE: To produce  $\text{Al}_2\text{O}_3$  glasses by levitation in zero g.

TOTAL PROCESS TIME: 2 hours.

## PROCESS:

| <u>Steps</u>                 | <u>Parameters</u>        |
|------------------------------|--------------------------|
| 1. Pressurize chamber.       | 1 atmosphere.            |
| 2. Insert sample.            | 0.4 in. diameter sphere. |
| 3. Levitate sample.          |                          |
| 4. Melt sample.              | 2,050°C.                 |
| 5. Hold at temperature.      | 5 minutes.               |
| 6. Cool sample.              | 100 minutes.             |
| 7. Retrieve and stow sample. |                          |

## SPECIAL HARDWARE:

- |                                    |       |
|------------------------------------|-------|
| 1. Manipulator.                    |       |
| 2. Furnace enclosure.              |       |
| 3. Levitation and mixer, acoustic. |       |
| 4. Resistance or imaging furnace.  | 2 kW. |
| 5. Gas control system.             |       |

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature/pressure/time profile.
3. Post-mission analysis.
  - (a) Measurement of optical properties.
  - (b) Correlation of measured properties with process parameters.



## EXPERIMENT DESIGNATION G-9

TITLE: Striking Glass

OBJECTIVE: To obtain uniform dispersion of modifying particulate (e.g., AgCl) in high-quality silicate glass.

TOTAL PROCESS TIME: 2 hours.

PROCESS:

| <u>Steps</u>                 | <u>Parameters</u>        |
|------------------------------|--------------------------|
| 1. Pressurize chamber.       | 1 atmosphere.            |
| 2. Insert sample.            | 1.5 in. diameter sphere. |
| 3. Levitate.                 |                          |
| 4. Melt sample.              | 1,500°C.                 |
| 5. Hold at temperature.      | 5 minutes.               |
| 6. Cool.                     | 136 minutes.             |
| 7. Retrieve and stow sample. |                          |

SPECIAL HARDWARE:

- |                                    |       |
|------------------------------------|-------|
| 1. Manipulator.                    |       |
| 2. Furnace enclosure.              |       |
| 3. Levitation and mixer, acoustic. |       |
| 4. Resistance or imaging furnace.  | 2 kW. |
| 5. Gas control system.             |       |

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature/pressure/time profile.
3. Post-mission analysis.
  - (a) Measurement of optical properties.
  - (b) Correlation of measured properties with process parameters.

## EXPERIMENT DESIGNATION M-1

TITLE: Containerless Preparation of Ultra-pure Alloys (e.g., Tungsten Carbide) and Unique New Compounds

OBJECTIVE: To obtain more accurate data on the mechanism of nucleation in alloys under zero g.

TOTAL PROCESS TIME: 40 minutes.

## PROCESS:

| <u>Steps</u>                 | <u>Parameters</u>                 |
|------------------------------|-----------------------------------|
| 1. Insert sample.            | 0.8 in. diameter sphere.          |
| 2. Levitate sample.          |                                   |
| 3. Evacuate chamber.         | $10^{-3}$ n/m <sup>2</sup> .      |
| 4. Heat sample.              | 2,200°C at 1 to 100°C per second. |
| 5. Vacuum outgassing.        | 20 minutes.                       |
| 6. Melt sample.              | 2,900°C.                          |
| 7. Hold at melt temperature. | 5 minutes.                        |
| 8. Cool.                     | 10 minutes.                       |
| 9. Retrieve and stow.        |                                   |

## SPECIAL HARDWARE:

1. Manipulator.
2. Furnace enclosure.
3. Levitation, stirrer, electromagnetic.
4. Vacuum system.
5. Cooling system, inert gas at 25°C.
6. Water quench system.
7. Electron beam gun. 10 kW.

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Sample temperature/pressure/time profile.
3. Post-mission analysis.
  - (a) Properties measurements and correlation with processing parameters.
  - (b) Photomicrograph.

## EXPERIMENT DESIGNATION M-2

TITLE: Whisker Reinforced Composites

OBJECTIVE: To strengthen base material with directionally oriented fibers (M561 Skylab).

PROCESS:

| <u>Steps</u>                           | <u>Parameters</u>    |
|--|----------------------|
| 1. Insert sample and evacuate chamber. | 10 cm <sup>3</sup> . |
| 2. Heat sample.                        | 500° to 1,600°C.     |
| 3. Cool sample.                        | -2°C per minute.     |
| 4. Retrieve sample.                    |                      |
| 5. Stow sample.                        |                      |

Total Time Estimate: 20 hours.

SPECIAL HARDWARE:

1. Manipulator.
2. Furnace with resistance heater.
3. Vacuum system.
4. Gas system.

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature and pressure profile of sample.
3. Post-mission analysis.
  - (a) Physical properties measurement.
  - (b) Correlation with process parameters.
  - (c) Photomicrograph.

## EXPERIMENT DESIGNATION M-3

TITLE: Immiscibility of Monotectic Alloy Systems (e. g., Tungsten-Copper)

RELATED CONTRACTS: NAS8-28267 and NAS8-27809.

OBJECTIVE: To investigate the influence of weightlessness on immiscibility of a monotectic alloy.

## PROCESS:

| <u>Steps</u>                 | <u>Parameters</u>    |
|------------------------------|----------------------|
| 1. Insert sample.            | 10 cm <sup>3</sup> . |
| 2. Evacuate chamber.         |                      |
| 3. Melt sample.              | Up to 3,410°C.       |
| 4. Cool sample.              |                      |
| 5. Retrieve and stow sample. |                      |

## SPECIAL HARDWARE:

1. Multipurpose furnace system.
2. Manipulator.
3. Vacuum system.
4. Gas system.

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature profile.
3. Post-mission analysis.
  - (a) Physical properties tests.
  - (b) Photomicrograph.
  - (c) Correlation of process parameters with physical characteristics.

## EXPERIMENT DESIGNATION M-4

TITLE: Supercooling and Homogeneous Nucleation (e.g., GaAs)

RELATED CONTRACTS: NAS8-28749 and NAS8-28604.

OBJECTIVE: To determine kinetics of nucleation and grain growth as functions of supercooling.

## PROCESS:

| <u>Steps</u>        | <u>Parameters</u>      |
|---------------------|------------------------|
| 1. Insert sample.   | 2 cm <sup>3</sup>      |
| 2. Heat sample.     | 1,250°C.               |
| 3. Levitate sample. |                        |
| 4. Cool sample.     | 1 to 100°C per minute. |
| 5. Retrieve sample. |                        |
| 6. Stow sample.     |                        |

## SPECIAL HARDWARE:

1. Manipulator.
2. Enclosure.
3. Levitation, electromagnetic. 2 kW.
4. Cooling system, inert gas at 25°C.

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature and time profile.
3. Post-mission analysis.
  - (a) Properties measurements and correlation with processing parameters.
  - (b) Photomicrograph.

EXPERIMENT DESIGNATION M-5

TITLE: Liquid State Forming (Membranes)

OBJECTIVE: To produce continuous lengths of ultra-thin membranes in zero g.

PROCESS STEPS:

1. Insert material, evacuate chamber.
2. Melt material.
3. Draw and spool membrane.
4. Retrieve and stow sample.

SPECIAL HARDWARE:

1. Manipulator.
2. Furnace.
3. Spooling mechanism.
4. Vacuum system.
5. Levitation, electromagnetic.

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature and time profile.
3. Post-mission analysis.
  - (a) Measurement of physical properties.
  - (b) Correlation of physical properties with processing parameters.

## EXPERIMENT DESIGNATION M-6

TITLE: Purification of Elements (e.g., Silicon) by Zone Refining

OBJECTIVE: To take advantage of zero g to purify materials with relatively low surface tension.

## PROCESS:

| <u>Steps</u>                        | <u>Parameters</u>        |
|-------------------------------------|--------------------------|
| 1. Insert sample rod.               | 50 cm x 2 cm diameter.   |
| 2. Evacuate chamber.                | $10^{-4}$ Torr.          |
| 3. Heat sample.                     | $1,410^{\circ}\text{C.}$ |
| 4. Move molten zone through sample. | 5 cm per hr.             |
| 5. Cool.                            |                          |
| 6. Retrieve and stow.               |                          |

Total time estimate: 24 hours.

## SPECIAL HARDWARE:

- |                   |       |
|-------------------|-------|
| 1. Manipulator.   |       |
| 2. Furnace.       | 3 kW. |
| 3. Vacuum system. |       |

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature and pressure profiles.
3. Post-mission analysis.
  - (a) Measurement of physical properties.
  - (b) Photomicrograph.
  - (c) Correlation of properties with processing parameters.

## EXPERIMENT DESIGNATION M-7

TITLE: Solidification of Composite Materials (e. g., aluminum with aluminum oxide fibers)

RELATED CONTRACT: NAS8-27806.

OBJECTIVE: To obtain data on characteristics and properties of composites produced under zero g.

## PROCESS:

| <u>Steps</u>                                | <u>Parameters</u>    |
|---|----------------------|
| 1. Insert sample cartridge.                 | 50 cm <sup>3</sup> . |
| 2. Heat sample.                             | 700°C.               |
| 3. Mix sample and hold at melt temperature. | 15 minutes.          |
| 4. Cool sample.                             |                      |
| 5. Retrieve sample.                         |                      |
| 6. Stow sample.                             |                      |

## SPECIAL HARDWARE:

1. Cartridge.
2. Manipulator.
3. Furnace.
4. Mixer.

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature and time profile, g-load.
3. Post-mission analysis.
  - (a) Physical properties measurement.
  - (b) Photomicrograph.
  - (c) Correlation of properties with processing parameters.



## EXPERIMENT DESIGNATION M-8

(Comparable to M557 Skylab)

TITLE: Solidification of Immiscible Materials (e. g., Copper and Lead)

RELATED CONTRACTS: NAS8-28267, -27809, -29725, and -29748.

OBJECTIVE: To determine effects of zero g on processing of material combinations which normally segregate on Earth.

## PROCESS:

| <u>Steps</u>                    | <u>Parameters</u>    |
|---------------------------------|----------------------|
| 1. Insert sample.               | 10 cm <sup>3</sup> . |
| 2. Heat sample.                 | 1,100°C.             |
| 3. Mix sample and hold at melt. | 15 minutes.          |
| 4. Cool sample.                 | 10 minutes.          |
| 5. Retrieve sample.             |                      |
| 6. Stow sample.                 |                      |

## SPECIAL HARDWARE:

- |                            |         |
|----------------------------|---------|
| 1. Manipulator.            |         |
| 2. Furnace.                | 2.2 kW. |
| 3. Mixer, electromagnetic. |         |

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature and time profile.
3. Post-mission analysis.
  - (a) Physical properties measurement.
  - (b) Photomicrograph.
  - (c) Correlation of properties with processing parameters.

EXPERIMENT DESIGNATION M-9

TITLE: Metals Melting (Similar to M551 Skylab)

OBJECTIVE: To study thermocapillary and other convection mechanisms operational in zero g.

PROCESS STEPS:

1. Position sample and evacuate chamber.
2. Energize electron beam gun for programmed time.
3. Cool.
4. Retrieve and stow sample.

SPECIAL HARDWARE:

1. Manipulator.
2. Electron-beam gun.
3. Vacuum system.
4. Levitation, electromagnetic.

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Electron-beam gun voltage and current.
3. Post-mission analysis.
  - (a) Properties measurements and correlation with process parameters.
  - (b) Photomicrography.

EXPERIMENT DESIGNATION M-10

TITLE: Sphere Forming (Similar to M553 Skylab)

OBJECTIVE: To compare metals melted and re-solidified in space with the same materials processed on earth to study solid/liquid/gas reactions in sphere formation.

PROCESS STEPS:

1. Position sample and evacuate chamber.
2. Energize electron-beam gun for programmed time.

SPECIAL HARDWARE:

1. Furnace.
2. Electron-beam gun.
3. Vacuum system.
4. Levitation, electromagnetic.

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Electron-beam gun voltage and current.
3. Post-mission analysis.
  - (a) Properties measurement and correlation with process parameters.
  - (b) Photomicrography.

EXPERIMENT DESIGNATION M-11

TITLE: Radioactive Tracer Diffusion (Comparable to M558 Skylab)  
(e.g., Zinc-65 in Neutral Zinc)

OBJECTIVE: To measure self-diffusion and impurity diffusion effects and to characterize the influence of spacecraft acceleration.

PROCESS STEPS:

1. Insert cartridge and evacuate chamber.
2. Energize furnace for programmed time and temperature.
3. Cool.
4. Retrieve and stow cartridge.

Total Time Estimate: 19 hr.

SPECIAL HARDWARE:

1. Resistance heater.
2. Manipulator.
3. Vacuum system.
4. Furnace enclosure.

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature and time profile; spacecraft acceleration.
3. Post-mission analysis.
  - (a) Properties measurement and correlation with process parameters.
  - (b) Photomicrography.

EXPERIMENT DESIGNATION M-12

TITLE: Microsegregation in Germanium (Comparable to M559 Skylab)

RELATED CONTRACT: NAS8-27891.

OBJECTIVE: To determine degree of microsegregation of doping impurities (e.g., gallium, antimony, and boron) incurred during directional solidification under zero g.

PROCESS STEPS:

1. Insert sample rod and evacuate chamber.
2. Heat sample.
3. Move molten zone through specimen. 5 cm per hr.
4. Cool.
5. Retrieve and stow sample.

Total Time Estimate: 29 hr.

SPECIAL HARDWARE:

1. Furnace enclosure.
2. Manipulator.
3. Vacuum system.
4. Resistance heater.

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature/pressure/time profile.
3. Post-mission analysis.
  - (a) Photomicrography.

EXPERIMENT DESIGNATION M-13

TITLE: Metal and Halide Eutectics (Comparable to M564 Skylab)

RELATED CONTRACT: NAS8-20402.

OBJECTIVE: To produce controlled structures in samples of eutectics.

PROCESS STEPS:

1. Insert sample and evacuate chamber.
2. Heat sample.
3. Cool.
4. Retrieve and stow sample.

Total Time Estimate: 27 hr.

SPECIAL HARDWARE:

1. Furnace.
2. Manipulator.
3. Gas system, e.g., argon at 25°C.
4. Vacuum system.
5. Resistance heater.

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature/pressure/time profile.
3. Post-mission analysis.
  - (a) Properties measurement and correlation with process parameters.
  - (b) Photomicrography.

EXPERIMENT DESIGNATION M-14

TITLE: Silver Grids Melted in Space (Similar to M565 Skylab)

OBJECTIVE: To determine how pore sizes and shapes change in grids of fine silver wires melted and re-solidified in space.

PROCESS STEPS:

1. Install sample and evacuate chamber.
2. Heat sample.
3. Cool.
4. Retrieve and stow sample.

Total Time Estimate: 19 hr.

SPECIAL HARDWARE:

1. Furnace enclosure.
2. Vacuum system.
3. Manipulator.
4. Resistance heater.

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature/pressure/time profile.
3. Post-mission analysis.
  - (a) Photomicrography.

## EXPERIMENT DESIGNATION M-15

(Comparable to M566 Skylab)

TITLE: Copper-Aluminum Eutectic

RELATED CONTRACT: NAS8-20402.

OBJECTIVE: To determine effects of weightlessness on termination faults and other defects in aligned eutectic material.

## PROCESS:

| <u>Steps</u>                          | <u>Parameters</u>    |
|---------------------------------------|----------------------|
| 1. Insert sample.                     | 10 cm <sup>3</sup> . |
| 2. Heat sample.                       | 1,084°C.             |
| 3. Move molten zone through specimen. | 5 cm per hr.         |
| 4. Cool.                              |                      |
| 5. Retrieve and stow.                 |                      |

## SPECIAL HARDWARE:

- |   |       |
|---|-------|
| 1. Furnace, resistance heater.          | 1 kW. |
| 2. Manipulator.                         |       |
| 3. Cooling system, e.g., argon at 25°C. |       |

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Temperature and time profile.
3. Post-mission analysis.
  - (a) Physical properties measurement.
  - (b) Photomicrograph.
  - (c) Correlation of properties with processing parameters.



EXPERIMENT DESIGNATION M-16

TITLE: Dispersion Strengthened Chromium

OBJECTIVE: To develop a strong chromium by uniform dispersion of tungsten carbide, molybdenum carbide, or various borides and nitrides.

PROCESS STEPS:

1. Insert sample.
2. Evacuate chamber.
3. Melt sample.
4. Mix.
5. Cool.
6. Retrieve and stow sample.

SPECIAL HARDWARE:

1. Furnace enclosure.
2. Resistance heater.
3. Vacuum system.
4. Manipulator.
5. Mixer.

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Process parameters.
3. Post-mission analysis.
  - (a) Physical characteristics measurement and correlation with process parameters.
  - (b) Photomicrography.

EXPERIMENT DESIGNATION M-17

TITLE: Ultra Pure Chromium

OBJECTIVE: To develop fine-grained chromium with minimum interstitial entrapment of nitrogen and oxygen.

PROCESS STEPS:

1. Insert sample.
2. Evacuate chamber.
3. Melt sample.
4. Levitate and spin sample.
5. Cool.
6. Retrieve and stow sample.

SPECIAL HARDWARE:

1. Enclosure.
2. Levitation, electromagnetic with spin capability.
3. Vacuum system.
4. Manipulator.

RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Process parameters.
3. Post-mission analysis.
  - (a) Physical characteristics measurement.
  - (b) Photomicrography.

## EXPERIMENT | DESIGNATION M-18

TITLE: Purification and Undercooled Solidification of Tungsten

RELATED CONTRACT: NAS8-29879.

OBJECTIVE: To obtain usable quantities of highly-purified fine-grain tungsten for commercial applications.

TOTAL PROCESS TIME: 50 minutes.

## PROCESS:

| <u>Steps</u>                 | <u>Parameters</u>        |
|------------------------------|--------------------------|
| 1. Insert sample.            | 0.6 in. diameter sphere. |
| 2. Evacuate chamber.         | $10^{-3}$ n per $m^2$ .  |
| 3. Levitate sample.          |                          |
| 4. Heat sample.              | 2,400°C.                 |
| 5. Dwell at temperature.     | 20 minutes.              |
| 6. Melt sample.              | 3,410°C.                 |
| 7. Hold at temperature.      | 5 minutes.               |
| 8. Cool sample.              | 10 minutes.              |
| 9. Retrieve and stow sample. |                          |

## SPECIAL HARDWARE:

|  |        |
|--|--------|
| 1. Manipulator.                            |        |
| 2. Furnace enclosure.                      |        |
| 3. Electromagnetic heating and levitation. | 100 W. |
| 4. Inert gas/vacuum system.                |        |
| 5. Water quenching system.                 |        |
| 6. Electron-beam gun.                      | 10 kW. |

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Process event times.
2. Process parameters.
  - (a) Temperature and time profile.
  - (b) Pressure and time profile.
3. Post-mission analysis.
  - (a) Physical properties measurement.
  - (b) Correlation with process parameters.
  - (c) Photomicrograph.

## EXPERIMENT DESIGNATION M-19

TITLE: Beryllia Dispersion in Beryllium

OBJECTIVE: To obtain uniform dispersion of beryllia in beryllium for possible commercial application as reflectors in nuclear reactors.

TOTAL PROCESS TIME: 45 minutes.

## PROCESS STEPS:

| <u>Steps</u>                 | <u>Parameters</u>                |
|------------------------------|----------------------------------|
| 1. Insert sample.            | 2 in. -diameter Boule.           |
| 2. Levitate.                 |                                  |
| 3. Evacuate chamber.         | $10^{-3}$ n per m <sup>2</sup> . |
| 4. Heat sample.              | 1,000°C.                         |
| 5. Dwell at temperature.     | 3 minutes.                       |
| 6. Melt sample.              | 1,300°C.                         |
| 7. Hold at temperature.      | 5 minutes.                       |
| 8. Cool sample.              | 10 minutes.                      |
| 9. Retrieve and stow sample. |                                  |

## SPECIAL HARDWARE:

|                                 |        |
|---------------------------------|--------|
| 1. Manipulator.                 |        |
| 2. Furnace enclosure.           |        |
| 3. Electromagnetic levitation.  | 100 W. |
| 4. Inert gas and vacuum system. |        |
| 5. Water quenching system.      |        |
| 6. Electron-beam gun.           | 10 kW. |

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Process parameters.
  - (a) Temperature and time profile.
  - (b) Pressure and time profile.
3. Post-mission analysis.
  - (a) Physical properties measurements.
  - (b) Correlation with process parameters.
  - (c) Photomicrograph.

## EXPERIMENT DESIGNATION M-20

TITLE: Amorphous Metallic Conductors (e.g., Palladium-Silicon)

OBJECTIVE: To develop new materials with unique properties for electronics applications.

TOTAL PROCESS TIME: 15 minutes.

## PROCESS:

| <u>Steps</u>                 | <u>Parameters</u>          |
|------------------------------|----------------------------|
| 1. Insert sample.            | 1.6 in. - diameter sphere. |
| 2. Levitate.                 |                            |
| 3. Evacuate chamber.         | $10^{-3}$ n per $m^2$ .    |
| 4. Melt sample.              | 960°C.                     |
| 5. Hold at temperature.      | 5 minutes.                 |
| 6. Cool sample.              | 5 minutes.                 |
| 7. Retrieve and stow sample. |                            |

## SPECIAL HARDWARE:

- |                                 |        |
|---------------------------------|--------|
| 1. Manipulator.                 |        |
| 2. Vacuum chamber.              |        |
| 3. Inert gas and vacuum system. |        |
| 4. Electromagnetic levitation.  | 100 W. |
| 5. Electron-beam gun.           | 10 kW. |

## RECORDING AND ANALYSIS REQUIREMENTS:

1. Event times.
2. Process parameters.
  - (a) Temperature/pressure/time profile.
3. Post-mission analysis.
  - (a) Physical properties measurement.
  - (b) Correlation with process parameters.
  - (c) Photomicrograph.

EXPERIMENT DESIGNATION P-1

TITLE: Physical Properties of Fluids Measurements (most experiments defined to date have been concerned with the role of convection)

OBJECTIVE: Define the role of gravity in fluid transport phenomena and generate data on non-gravity-dependent phenomena normally masked by gravitational effects.

PROCESS STEPS:

Measurements and observations made during performance of other space processing experiments.

SPECIAL HARDWARE:

As this is not a manufacturing process, but a properties measurement experiment, custom hardware can be carried on each designated flight, as required.

RECORDING AND ANALYSIS REQUIREMENTS:

Process parameters.

## APPENDIX B

## CHAMBER ENVIRONMENTAL CONTROL AND MONITORING

## B.1 REQUIREMENTS

The chamber environment for L-1 processes must be maintained between  $10^{-5}$  and  $10^{-7}$  Torr (approximately  $10^{-3}$  to  $10^{-5}$  N/m<sup>2</sup>). This is for effective electron-beam gun operation and for outgassing of impurities during purification processes. A 2-ft (0.6 m) diameter spherical chamber is used. This chamber has a volume of 4.2 cu ft (118.5 l) and a surface area of 12.6 sq ft ( $11.7 \times 10^3$  cm<sup>2</sup>). The chamber material is electro-polished stainless steel baked out at 200 °C (473 °K) for 24 hr. This material has an outgassing rate of  $10^{-10}$  Torr l/cm<sup>2</sup>/sec at ambient and approximately  $10^{-8}$  Torr l/cm<sup>2</sup>/sec at 200 °C (reference). Assuming 350 hr from the time external pumping on the ground is removed until orbital operations, the pressure rise is to about  $2 \times 10^{-4}$  Torr (0.03 N/m<sup>2</sup>); so venting is required.

The vent line will be used to pump the system down during ground testing operations. Therefore, the vent line and pump combination must be sized so that a reasonable pumpdown time is achieved during testing. If an outgassing rate of  $10^{-4}$  Torr l/sec is realized, the pumping speed required to obtain  $10^{-5}$  ( $1.3 \times 10^{-3}$  N/m<sup>2</sup>) is a minimum of 10 l/sec. This includes the pump capability and the conductance of any lines leading to the pump from the chamber. Assuming a 2-in. (5 cm) portable vacuum pumping system of 175 l/sec pumping capability and providing a pumping speed of double the requirement to 20 l/sec, the line conductance required to provide 20 l/sec effective pumping speed with an efficiency of 50% in the portable unit is 25 l/sec. This corresponds to a 2-in. (5 cm) line 24 in. (60 cm) long or a 4-in. (10 cm) line 197 in. (500 cm) long, as shown in Figure B-1. The time required to pump the system from atmospheric pressure to  $10^{-5}$  Torr ( $1.3 \times 10^{-3}$  N/m<sup>2</sup>) is, then, about 12 min. If higher outgassing rates are experienced, the system will require a longer pumpdown time. This indicates how imperative it is to achieve and maintain a clean vacuum system and to avoid the use of highly outgassing materials.

The sample to be processed for L-1 is 0.4 oz (10 g) of tungsten. The impurities outgassed represent 100 ppm by weight of the sample (Ref 1).<sup>\*</sup> The residual gases to be monitored and their atomic mass numbers are:

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<sup>\*</sup> References can be found in Paragraph B.3, the last paragraph of Appendix B.

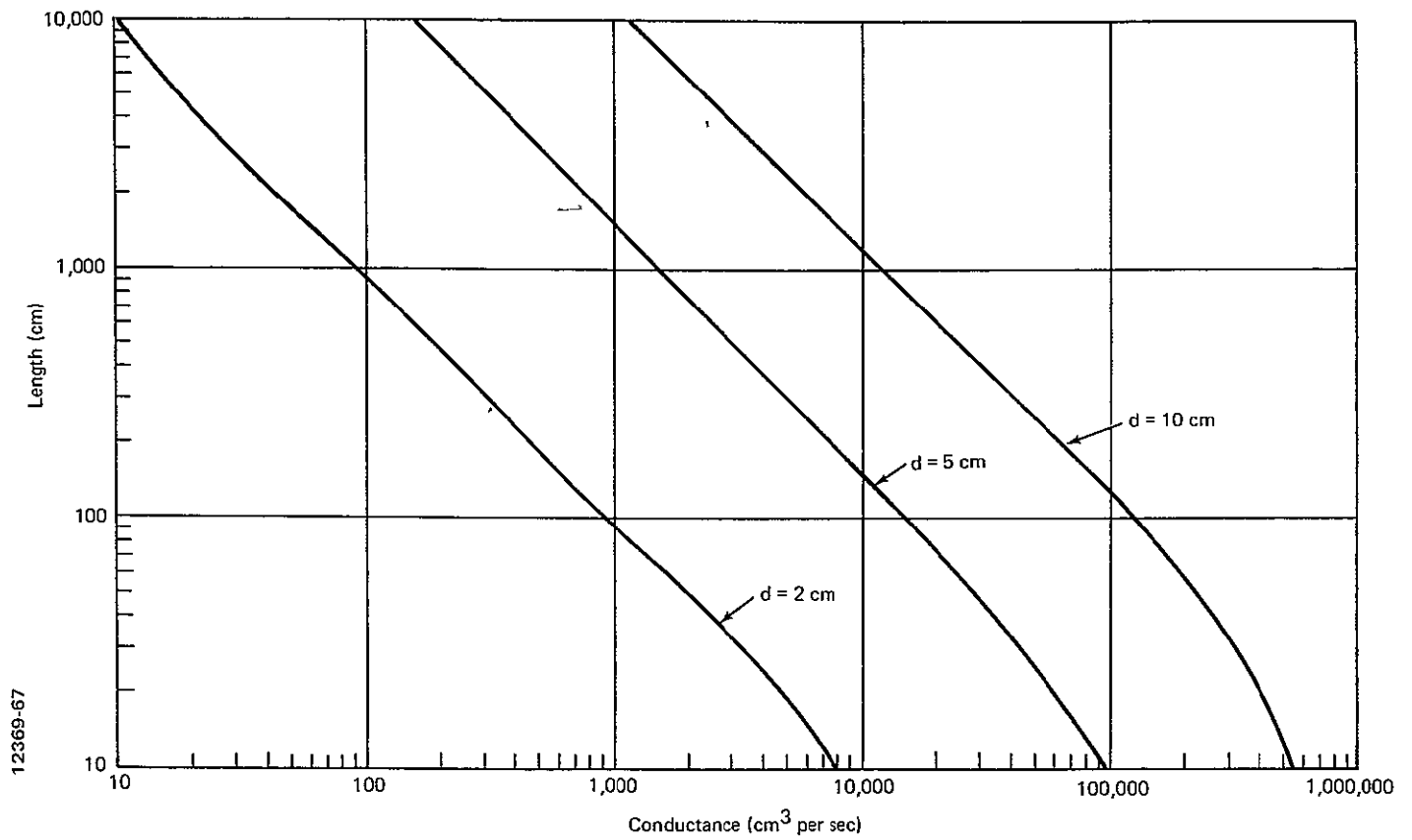


Figure B-1 Cylinder Tube Conductance for Modular Flow

| <u>Gases</u>     |              | <u>Atomic Mass Numbers</u> |
|------------------|--------------|----------------------------|
| H <sub>2</sub> O |              | 18.016                     |
| O <sub>2</sub>   | 20 to 40 ppm | 32.000                     |
| N <sub>2</sub>   | 2 to 10 pm   | 28.016                     |
| CO               |              | 28.010                     |
| CO <sub>2</sub>  |              | 44.010                     |
| H <sub>2</sub>   | 2 to 10 ppm  | 2.016                      |
| CH               |              | 16.042                     |
| C                | 20 to 40 ppm | 12.010                     |



One hundred ppm of the 10 g sample produces  $10^{-3}$  g of gases. Gas densities are  $N_2 = 1.2506$  g/l,  $O_2 = 1.429$  g/l and carbon dioxide = 1.977 g/l. Using an average gas density of 1.5 g/l, approximately  $6.7 \times 10^{-4}$  l of gas is produced at standard temperature and pressure (0 °C and 760 Torr).

In the 118.5 l volume at an average temperature of 200 °C, the total gas evolved is 0.882 Torr l. If the process time is 10 min, the average rate of outgassing is  $1.47 \times 10^{-3}$  Torr l/sec. The pumping speed required at this rate to maintain  $10^{-5}$  Torr or less pressure is 147 l/sec. For larger gas loads than expected, the process time may be extended or the system vented to obtain  $10^{-5}$  Torr operating pressure within the pumping capability.

The chamber outgasses at a rate of  $10^{-8}$  Torr l/cm<sup>2</sup>/sec at 200 °C. The total outgassing is  $1.17 \times 10^{-4}$  Torr l/sec. If the pumping speed is 147 l/sec, the pressure rise is  $8 \times 10^{-7}$  Torr ( $10^{-4}$  N/cm<sup>2</sup>) above the background at the maximum outgassing rate.

The chamber/spacelab vent interface will be a 2-in. (5-cm) diameter vent line. The external environment to which this vent is let is approximately  $6 \times 10^{-5}$  Torr ( $8 \times 10^{-3}$  N/m<sup>2</sup>) (Ref 2). The vent is used as a roughing pump to bring the chamber to a safe operating condition if a gas overload occurs and the pressure rises to  $10^{-4}$  Torr (0.01 N/m<sup>2</sup>) or greater. At this point, the ion pump is closed off and the vent line is used to lower the chamber to a safe operating limit for the pump ( $10^{-5}$  Torr or less). If we allow 5 min to vent the chamber to  $10^{-5}$  Torr ( $1.3 \times 10^{-3}$  N/m<sup>2</sup>), a conductance of about 1 l/sec is required. The tube conductance as a function of length and diameter is shown in Figure B-1.

A real time knowledge of the chamber pressure is essential to prevent damage to equipment and samples. The pressure range is from  $10^{-3}$  Torr to less than  $10^{-7}$  Torr (0.1 to  $10^{-5}$  N/m<sup>2</sup>). There are several pressure points where, through programming and sensing, events must occur. These are between  $10^{-5}$  and  $10^{-4}$  Torr. It is within this range that the system is switched from the ion pump to the vent line, and the electron-beam gun and residual gas analyzer are switched on and off. This requires a total pressure sensor having a range of at least  $10^{-6}$  to  $10^{-2}$  Torr ( $10^{-4}$  to 1.3 N/m<sup>2</sup>). If the need arises to read lower pressures, an ultra-high vacuum ionization gauge can be added, although this data can be obtained from the residual gas analyzer.

The partial pressures of the non-condensable gases are measured during this purification process so that some measure of increasing sample purity is known in real time. Such information is used to determine the "end of dwell" when, for instance, the  $O_2$  peak drops below the  $H_2$  peak or other known relationships. The

residual gas analyzer should have a minimum mass range of 1 to 50 AMU and a dynamic range of  $10^6$  with a minimum nitrogen detectability of at least  $10^{-10}$  Torr (10 ppm at  $10^{-5}$  Torr). No special sample inlet system is required, as the system operation is to be maintained at about  $10^{-5}$  Torr (a safe operating limit for most gas analyzers). The gas analyzer will be equipped with a small (2 to 8 l/sec) pump to maintain sample response at a high rate.

## B.2 SYSTEM IMPLEMENTATION

Figure B-2 shows an implementation of the vacuum system and pumping for the L-1 facility. Access to the main chamber is through gate valves 1 and 2, which are pneumatically-actuated and sealed. A gas storage and regulation system is provided to operate the valves. The gas is nitrogen or air at 1,500 psi (10.3 MN/m<sup>2</sup>). Regulation to 600 psi (4.1 MN/m<sup>2</sup>) provides operation of the bellows seal and further regulation to 60 psi (0.41 MN/m<sup>2</sup>) provides gas for operation of the valve actuator assembly. Figure B-3 shows a schematic drawing of the gate valve illustrating the actuator and seal operation. The four-way valves designated V<sub>1</sub> and V<sub>4</sub> in Figure B-2 are used to control the actuator assemblies. In one position, gas is fed to one side of the actuator assembly while the other side is vented. In the second position, the first side is vented while gas is fed to the other side of the actuator. Valves V<sub>2</sub>, V<sub>3</sub>, V<sub>5</sub>, and V<sub>6</sub> are used to control the valve sealing and unsealing. Specifications for the gate valve are summarized in Table B-1. The vent valve, V<sub>2</sub>, is a motorized butterfly valve. Figure B-4 shows the valve and its primary features.

Table B-1  
Gate Valve Specifications

|                                       |   |
|---------------------------------------|---|
| Bakeout temperatures                  | 300 °C (573 °K) valve open; 200 °C (473 °K) for 8-hr intervals with valve closed.         |
| Flow path                             | 3.0-in. (7.6-cm) flange face-to-forge face.   |
| Maximum sealing pressure              | 500 psig (3.4 MN/m <sup>2</sup> ).  |
| Nominal closing time from full open   | 1 sec.  |
| Nominal sealing time from full closed | 1 sec.  |
| Weight                                | 47 lb (21 kg).  |
| Pneumatic requirements                | Nitrogen or other inert gas at a pressure greater than 600 psig (4.1 MN/m <sup>2</sup> ). |

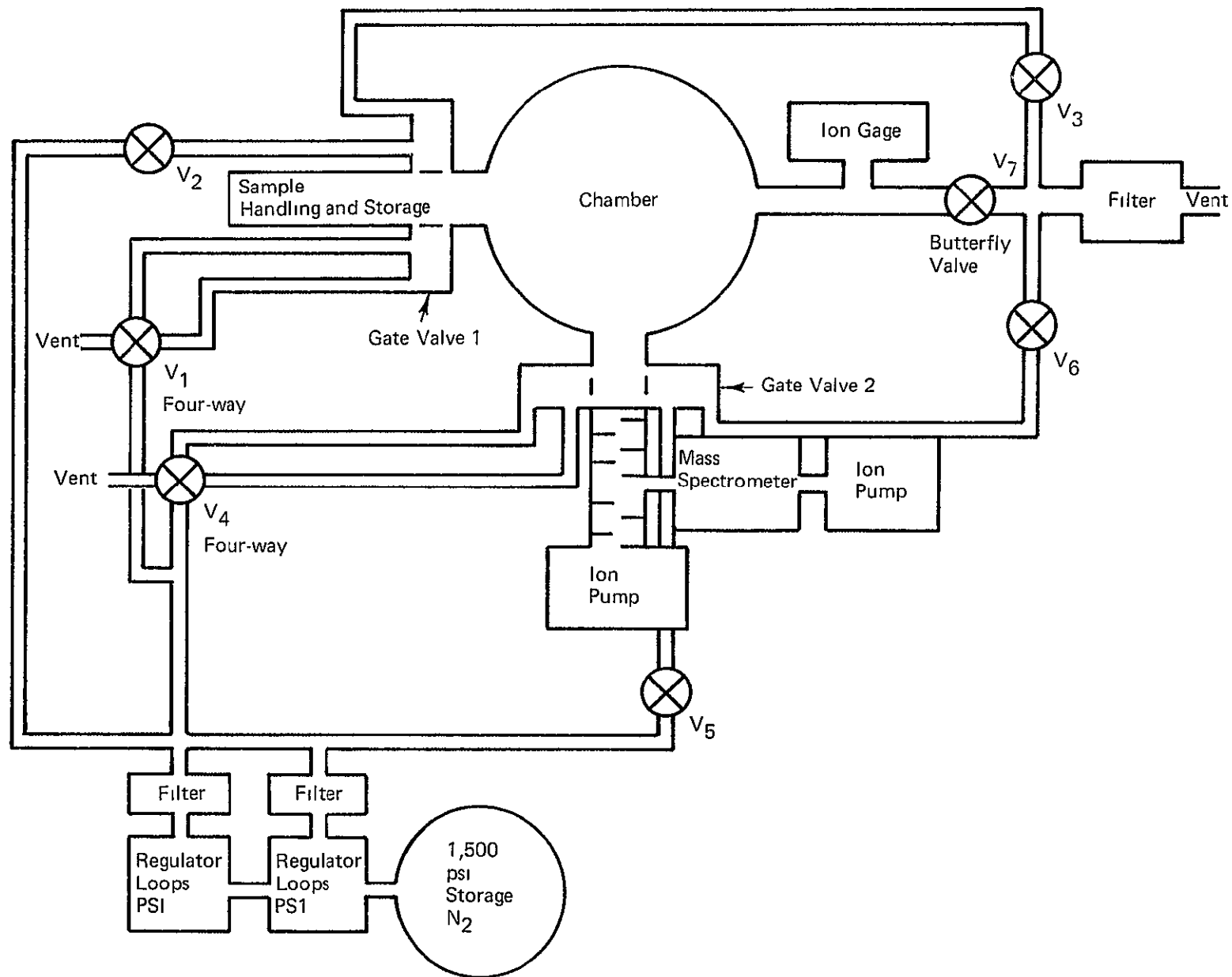
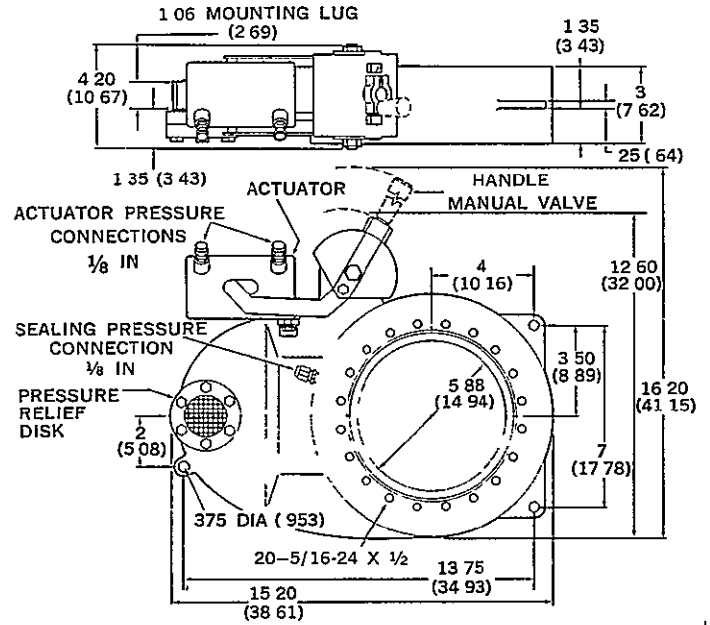
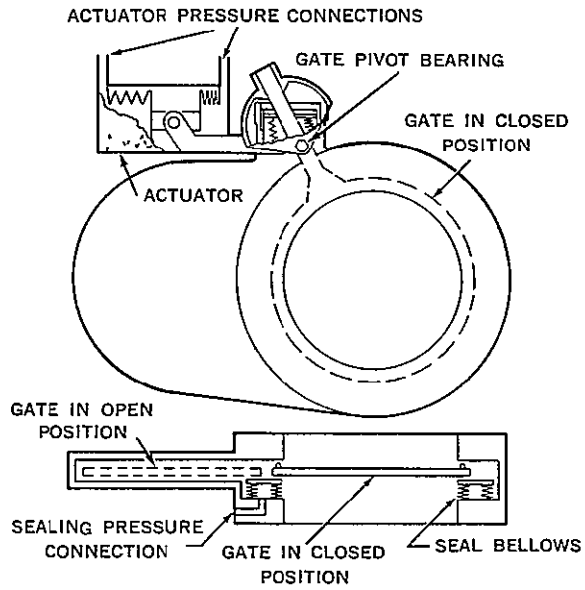


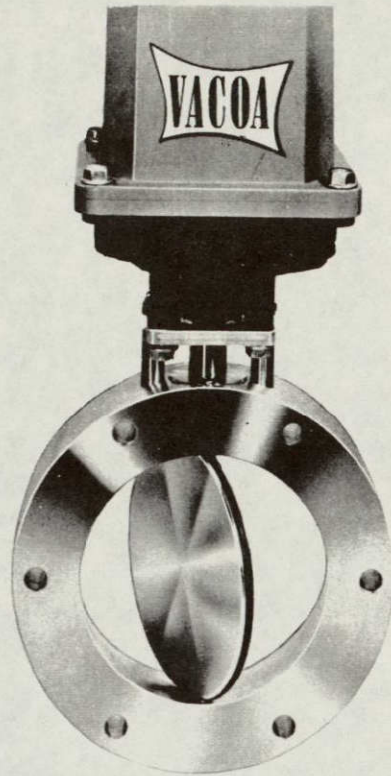
Figure B-2 Vacuum System Schematic Diagram



ALL DIMENSIONS SHOWN ARE IN INCHES (CENTIMETERS)

Figure B-3 Gate Valve Schematic Diagram

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**FEATURES—**

- MOTORIZED VERSION HAS CHOICE OF OUTPUT SPEEDS FROM OPEN TO CLOSE OF 2 SEC., 8 SEC., 16 SEC., AND 30 SEC.
- STANDARD VOLTAGES ARE 120 VAC 60/50 Hz, AND 220 VAC 60/50 Hz, 1 PHASE.
- OPTIONAL VOLTAGES ARE AVAILABLE ON SPECIAL APPLICATION 12, 24 AND 125 VDC.
- CAM OPERATED ADJUSTABLE LIMIT SWITCHES WITH EXTERNAL POSITION INDICATOR.
- ENCLOSURE NEMA #4 STANDARD WATERTIGHT. OPTIONAL NEMA #7.
- HIGH CONDUCTANCE STRAIGHT THRU PORTS, WITHOUT TRAPPED DEAD VOLUME AREAS COMMON TO SLIDE OR GATE VALVES.
- VITON "A," "O" RINGS SEALS FOR LOW OUTGASSING PROPERTIES AND PERMIT BAKING TO 225°C.
- ULTIMATE PRESSURES OF LOW  $10^{-1}$  TORR ARE OBTAINABLE.
- SIZES AVAILABLE ARE 2", 4", 6", 8", 10".
- VALVES ARE EASILY MAINTAINED. LONG SEAL LIFE ALLOWS FOR OVER 50,000 CLOSURES WITHOUT NEED TO REPLACE "O" RING SEAL.
- VALVES ARE GUARANTEED LEAK TIGHT TO HELIUM LEAK DETECTOR HAVING SENSITIVITY OF  $5 \times 10^{-11}$  STD CC/SEC.

12369-70

Figure B-4 Butterfly Vent Valve

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The requirements analysis has shown that an ion pump of approximately 140 l/sec pumping speed is required. A triode ion pump will be used. This pump has a varying pumping speed characteristic depending on the gas pumped as follows:

| <u>Gas</u>     | <u>Percent</u> | <u>Gas</u>        | <u>Percent</u> |
|----------------|----------------|-------------------|----------------|
| Air            | 100            | Light hydrocarbon | 90 to 105      |
| Hydrogen       | 200            | Water vapor       | 100            |
| Nitrogen       | 95             | Most inerts up to | 30             |
| Oxygen         | 57             |                   |                |
| Carbon dioxide | 100            |                   |                |

Since oxygen is one of the most likely gases to be encountered in the system, a 250 l/sec pump, which provides a 143 l/sec speed for oxygen, has been selected. Figure B-5 shows the pump speed versus pressure for this pump and Figure B-6 shows the pump pressure versus current characteristics. The pump weighs 180 lb (81 kg) and the control unit weighs 70 lb (32 kg), for a total weight of 250 lb (113 kg). The start-up current is 12 A maximum at 230 V. The operating current is as shown in Figure B-6.

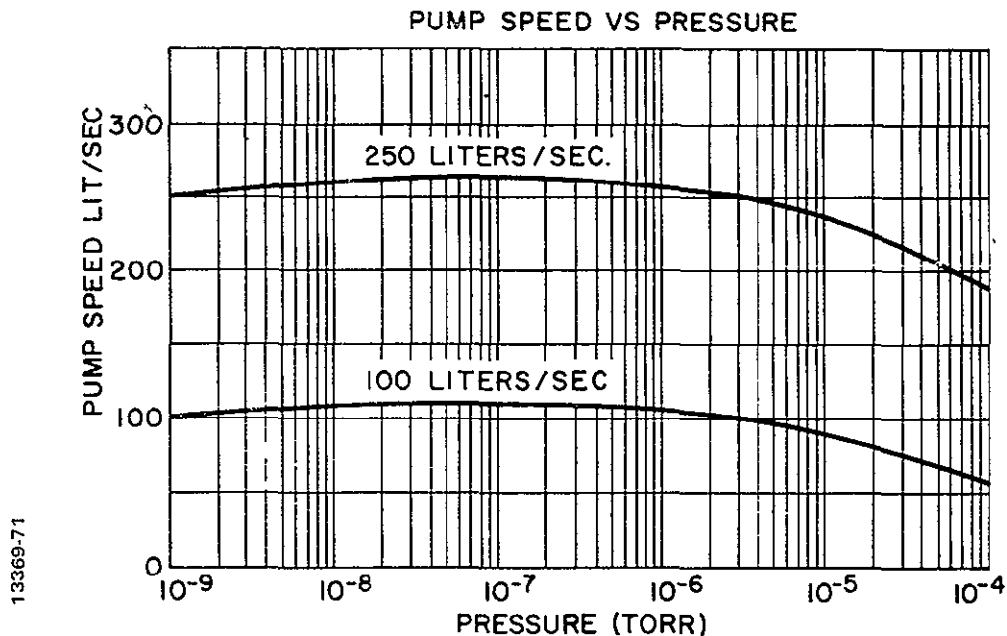


Figure B-5 Pump Speed versus Pressure

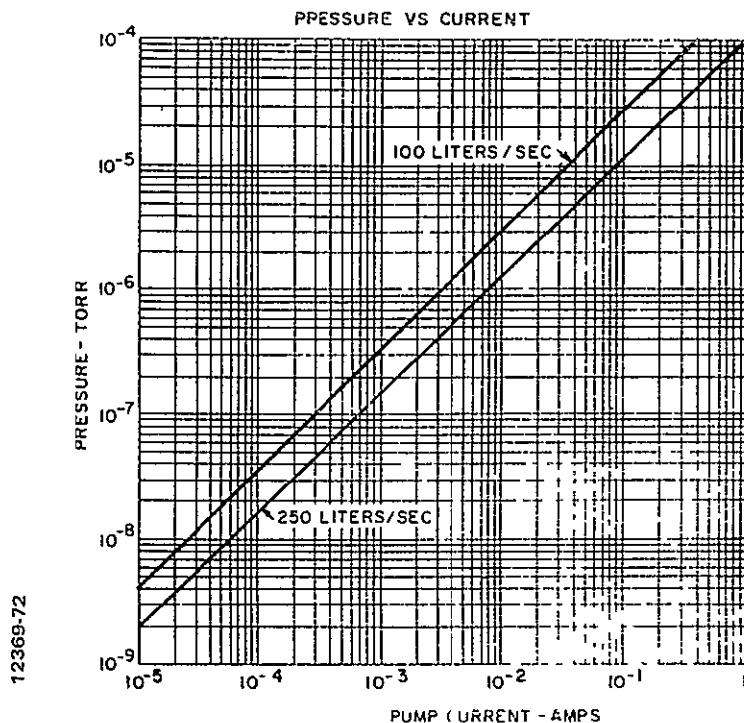
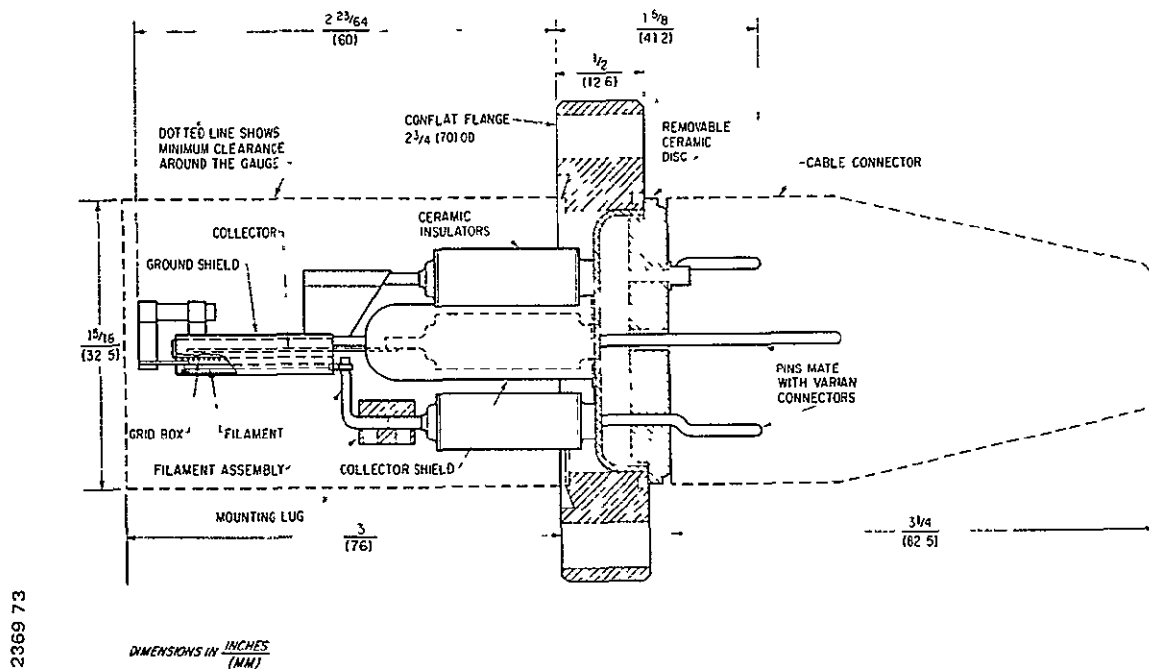


Figure B-6 Pump Pressure versus Current

The control vacuum gauge must have a minimum range of  $10^{-3}$  to  $10^{-6}$  Torr (approximately  $10^{-1}$  to  $10^{-4}$  N/m<sup>2</sup>). The Varian millitorr gauge provides accurate pressure measurement and fast response over the range of 0.6 to below  $10^{-6}$  Torr ( $80$  to  $1.3 \times 10^{-4}$  N/m<sup>2</sup>). The gauge is shown in Figure B-7. Characteristics of the gauge are summarized in Table B-2.

For residual gas analysis, the Viking Upper Atmospheric Mass Spectrometer (VUAMS) would meet most of the requirements. The 1-in. (2.54 cm) radius double-focused Mattauch-Herzog instrument has a mass range of 1 to 50 AMU and has been space-qualified. The instrument has a 5-sec scan time, a total pressure range of  $2 \times 10^{-7}$  to  $3 \times 10^{-4}$  Torr ( $3 \times 10^{-5}$  to  $4 \times 10^{-2}$  N/m<sup>2</sup>) and is capable of detecting a minimum partial pressure of  $10^{-10}$  Torr (approximately  $10^{-8}$  N/m<sup>2</sup>), which represents a gas content of 10 ppm at  $10^{-5}$  Torr. The instrument is equipped with a 2-l/sec ion pump for sample throughput. It weighs about 12 lb (5 kg) and requires 9 W average power and 17 W peak at 24 to 37 Vdc input. The only modification which might be required would be replacement of the Faraday cup readout system with an electron multiplier, for greater sensitivity. A commercial unit which may be used for the analysis is the UTI Precision Gas Analyzer Model 100B,



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Figure B-7 Millitorr Gauge

which has a mass range of 1 to 250 AMU, detects a minimum partial pressure of  $10^{-14}$  Torr (approximately  $10^{-12}$  N/m<sup>2</sup>) and weighs 75 lb (34 kg) and requires 330 W of power. Use of this instrument requires extensive electronics repackaging and change of readout techniques.



Table B-2

## Millitorr Gauge Characteristics

|                        |   |
|------------------------|---|
| Pressure range         | 0.6 to $1 \times 10^{-6}$ Torr<br>(80 to $1.3 \times 10^{-4}$ N/m <sup>2</sup> ).                               |
| Emission current       | 5 to 15 $\mu$ A<br>(Pressure in Torr = $10^5$ x collector current).   |
| Sensitivity            | $S = \frac{\text{collector current}}{\text{grid current} \times \text{pressure}}$<br>$= 0.5 (\text{Torr})^{-1}$ |
| Filament               | Thoria-coated iridium   |
| Grid Box               | Platinum iridium wire, mounted on stainless-steel structure.  |
| Collector              | Tungsten wire.  |
| Degas method           | Electron bombardment.   |
| Bakeability            | 450 °C (723 °K).  |
| Orientation            | Any.  |
| Process control output | Two relay circuits.<br>Delay time 1 sec.<br>Connections 28 Vdc, 2 A.<br>Normally closed or normally open.       |
| Weight                 | 20 lb (9 kg) including control unit.  |
| Input power            | 120/240 Vac, 50 to 60 Hz, 1.5 A.  |

## B.3 APPENDIX B REFERENCES

1. Study of Identification of Beneficial Uses of Space, Phase II, Final Report - Volume II, Book 1, Space Div, General Electric Co., Nov 1973.
2. Scialdone, J. J., Self Contamination and Environment of an Orbiting Spacecraft, NASA TND-6645, May 1972.
3. Turnbull, A. H., Barton, R. S., and Riviere, J. C., An Introduction to Vacuum Technique, John Wiley and Sons Inc., New York, 1962.
4. Dushmen, S., Scientific Foundation of Vacuum Technique, John Wiley and Sons Inc., New York, 1949.

## APPENDIX C

METHOD FOR COLLECTION AND STORAGE OF  
ELECTROPHORETICALLY-SEPARATED SAMPLES

This section describes an approach for handling and storing the output products of the ASPPS electrophoresis experiment. This basic approach uses an indexable storage drum, with the following developments:

- The use of an array of hypodermic needles to puncture and inject the separated fractions into sealed evacuated vials (rather than aligning and sealing an array of ports as before).
- The use of a pumped-coolant loop (rather than integral thermoelectric devices) to refrigerate the collected fractions.

The approach also differs from others in that it doesn't use a gang of suction pumps to transfer the numerous fractions from the separation chamber. The approach is based on the fundamental premise that, with the chamber at uniform pressure, a set of uniformly high flow restrictions at the output will result in a uniform flow-rate through each. In this case, the flow restrictions are the 56 hypodermic passages. The passages are deliberately made much smaller than other flow passages in the system, and would be selected for uniform internal diameter.

## C.1 FLOW

A brief analysis of the above approach is advisable before describing the hardware concept. We wish to evaluate the flow stability and pressure drop through the hypodermic passages. Assume that the fluid properties of the buffer solution are equivalent to water at 20 °C or:

$$\mu = \text{absolute viscosity (about } 10^{-2} \text{ gmm/cm sec).} \quad (1)$$

$$\rho = \text{density (about } 1 \text{ gmm/cm}^3\text{).}$$

$$v = \text{kinematic viscosity } \Delta \frac{\mu}{\rho} \text{ (about } 10^{-2} \text{ cm}^2\text{/sec).}$$

The maximum flow rate,  $Q$ , during separation and purging is specified as 300 ml per hr and 1,200 ml per hr, respectively. The flow velocity,  $V$ , in one passage of diameter  $D$  is, thus:

$$\begin{aligned}
 V &= \frac{1}{56} \frac{Q \text{ (total)}}{(\pi/4) D^2} \\
 &= 2.27 \times 10^{-2} \frac{Q}{D^2} \text{ (cm/hr)} \\
 &= 6.3 \times 10^{-6} \frac{Q}{D^2} \text{ (cm/sec), where}
 \end{aligned} \tag{2}$$

$Q$  is in ml/hr and  $D$  is in cm. The corresponding Reynolds number

$$N_R \triangleq \frac{VD}{\nu}$$

becomes

$$N_R = 6.3 \times 10^{-4} \frac{Q}{D}. \tag{3}$$

For  $Q = 300$  to  $1,200$  ml/hr, the Reynolds numbers are:

$$\begin{aligned}
 N_R \text{ (separation)} &= \frac{18.9 \times 10^{-2}}{D} \quad \text{and} \\
 N_R \text{ (purge)} &= \frac{75.6 \times 10^{-2}}{D},
 \end{aligned}$$

which indicate that the flow will be laminar for passage diameters between  $10^{-1}$  and  $10^{-2}$  cm. That is, the Reynolds numbers are considerably below the critical value  $N_{CR} \geq 2 \times 10^3$  at which the flow regime would tend to become unstable.

The pressure drop, as given by the D'Arcy Weisbach equation

$$\Delta P = f \frac{L}{D} \frac{V^2}{2g} \rho, \text{ where } f_{\text{laminar}} = \frac{64}{N_R} \tag{4}$$

reduces to the Poiseuille relationship for flow dominated by viscosity:

$$\Delta P = \frac{8QL}{\pi \left(\frac{D}{2}\right)^4} \frac{\mu}{g} \times \left(\frac{1}{56}\right) \left(\frac{\text{hr}}{3,600 \text{ sec}}\right). \tag{5}$$

Substituting Equation 1 into Equation 5, or Equation 2 and Equation 3 into Equation 4, gives

$$\Delta P \simeq 20 \times 10^{-10} \frac{QL}{D^4} \text{ dynes/cm,} \quad (6)$$

where L and D are the length and diameter of one hypodermic tube and Q is the total flow in ml/hr. Assuming L = 1.5 cm and D =  $10^{-2}$  cm gives

$$\Delta P_s = 92 \text{ dynes/cm}^2 = 1.3 \text{ psi}$$

for the maximum separation flow (300 ml/hr), and

$$\Delta P_p = 368 \text{ dynes/cm}^2 = 5.2 \text{ psi}$$

at the 1,200-ml/hr purge flow.

Thus, the total flow-rate through the apparatus would be metered by varying the speed of positive-displacement buffer and sample-input injection pumps, capable of working into the chamber pressure determined by L and D.

## C.2 APPROACH

An exploded view of the handling and containment approach is shown in Figure C-1. The 56 outputs from the electrophoresis chamber are routed through nominally 1-mm passages to a 4 by 14 array of hypodermic needles. The needles mate with a corresponding 4 by 14 array of sealed collection vials. Presuming four sample separations per mission, four sets of vials are mounted on an octagonal storage drum. Each vial array is sealed in a chamber in the drum and refrigerated by a flow of liquid coolant via ports designated C in the figure. Between each set of vial chambers are drain chambers for removing the purging buffer solution via ports designated P. A mechanism provides the insertion, retraction, and 45° drum rotation between collection and purge positions.

Figure C-2 is an enlarged cross-section of one possible needle and collection-vial configuration. Each vial is evacuated in an earth laboratory and sealed with a plug. The end of the plug has an elastomer wall, similar to a pharmaceutical septum, which is pierced by the hypodermic needle to fill the vial. The wall prevents leakage of the contents when the needle is withdrawn. As shown, the plug also has a collar for mounting and sealing the vials in a drilling plate matching the hypodermic array. The plate is, in turn, sealed to the coolant chamber by a gasket.

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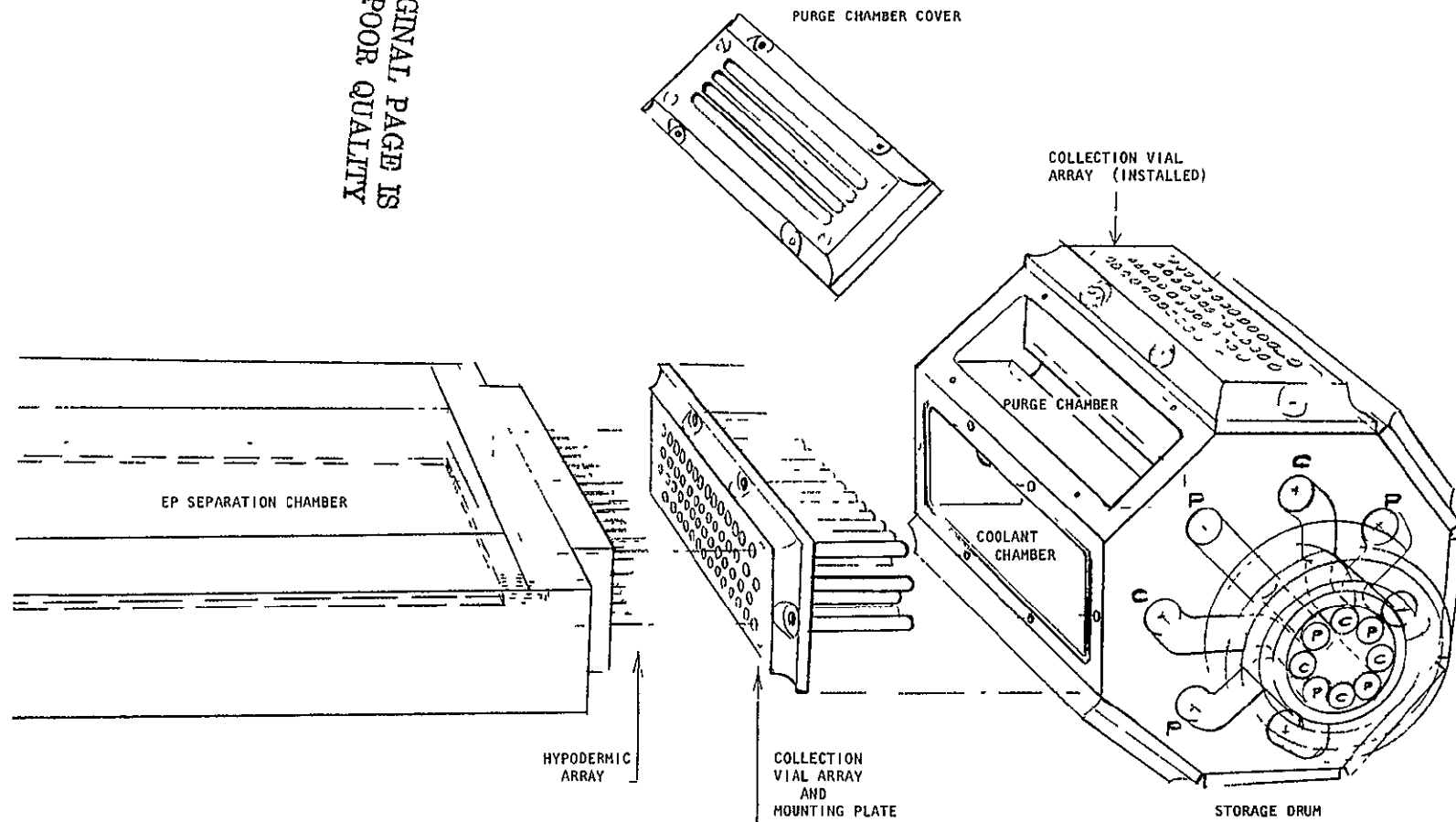


Figure C-1 Electrophoresis Sample Collection

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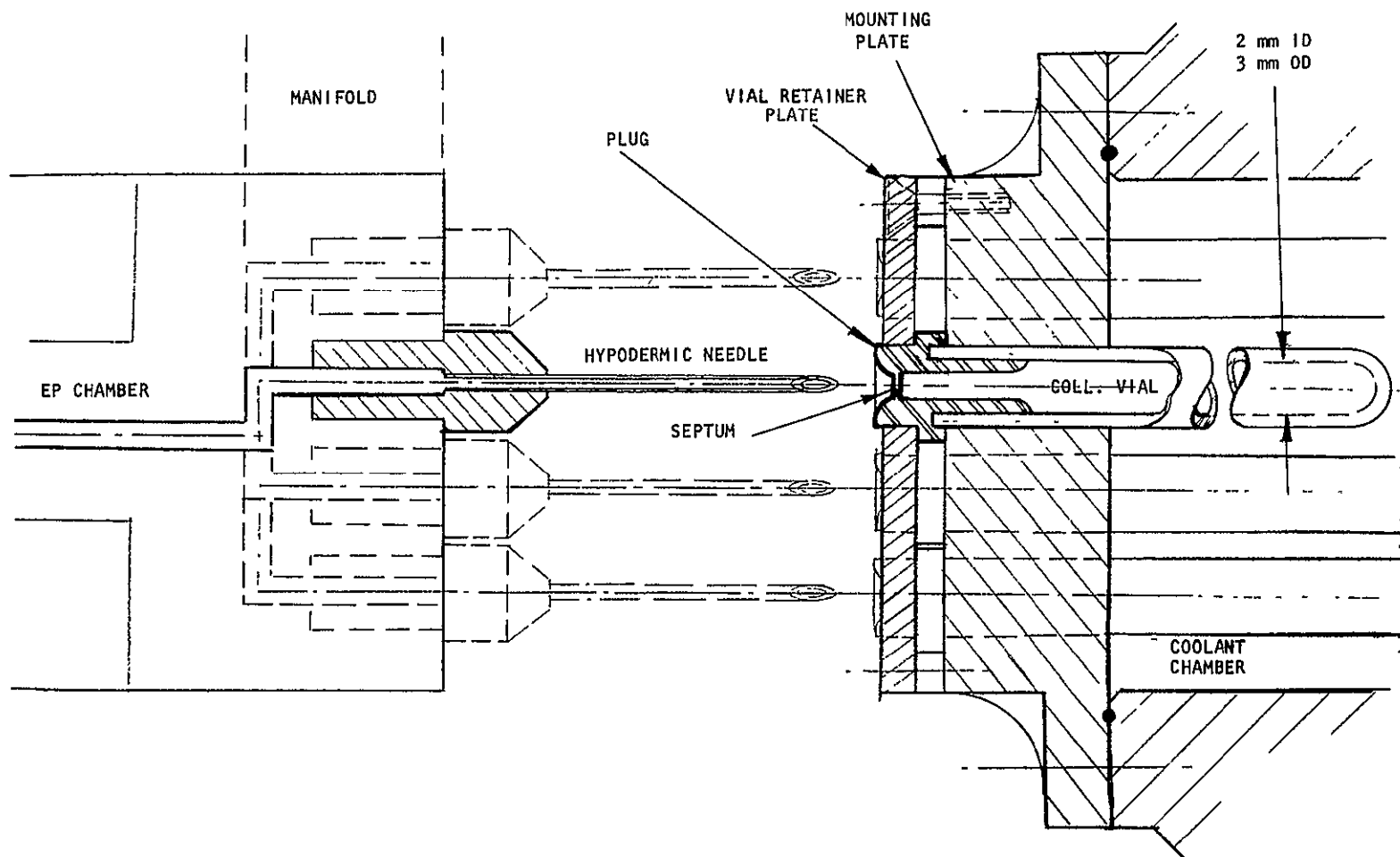


Figure C-2 Section through Needle and Vial

With a 2-mm inner diameter, the vial length would have to be about 32 mm to provide the 0.1-ml specified capacity. The vials, however, need not have rigid walls, as implied by the sketch. Thin flexible walls which collapse when evacuated may be more desirable, in order to give a visual indication that the vials are evacuated when installed.

Figure C-3 is a cross-section of a portion of the array. Four rows were chosen to obtain reasonable (3 to 4 mm) diameters to work with. The only reason for the array arrangement shown is to put the odd-numbered channels in the top rows and the even-numbered channels on the bottom rows.

Figure C-4 is a full-scale view of the device, shown just before insertion. A 1-cm linear motion would be provided by a mechanism (not shown) to move either the drum or the separation chamber. The needles are arranged in a "chevron" to minimize the puncture force required. The needle lengths are, of course, identical (per dotted line L-L in the figure).

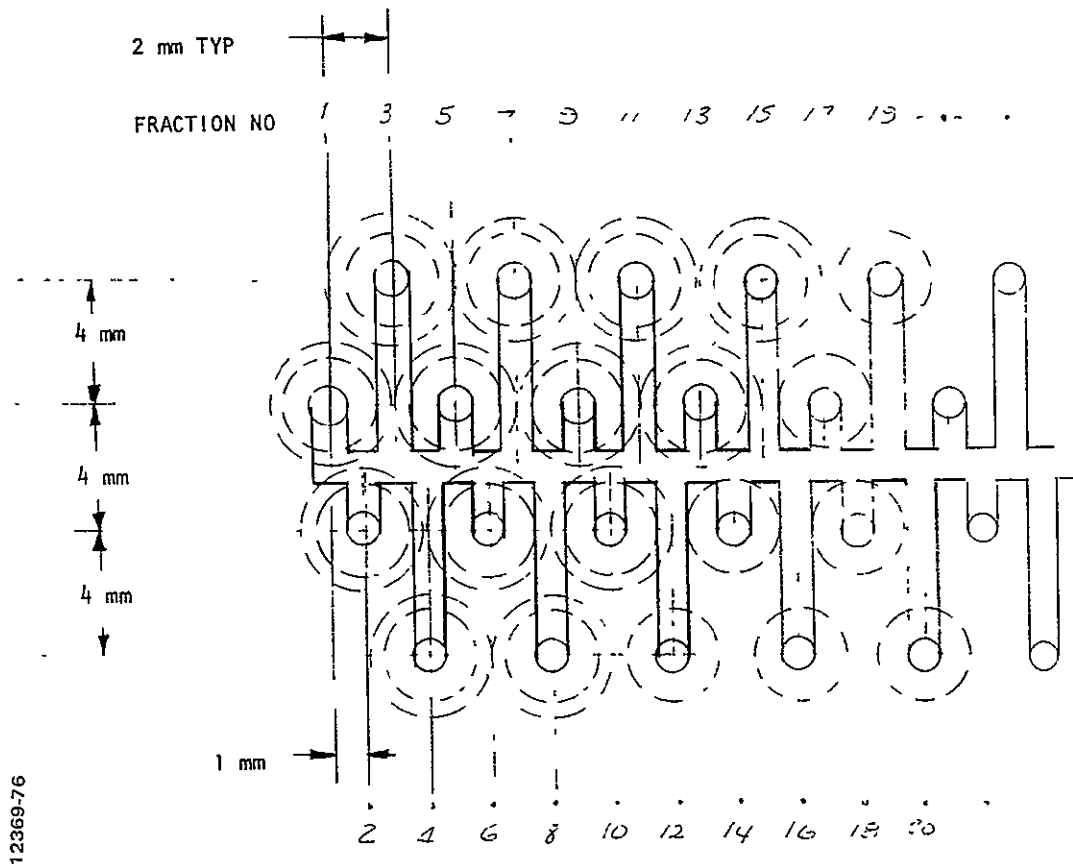


Figure C-3 Cross Section through Array

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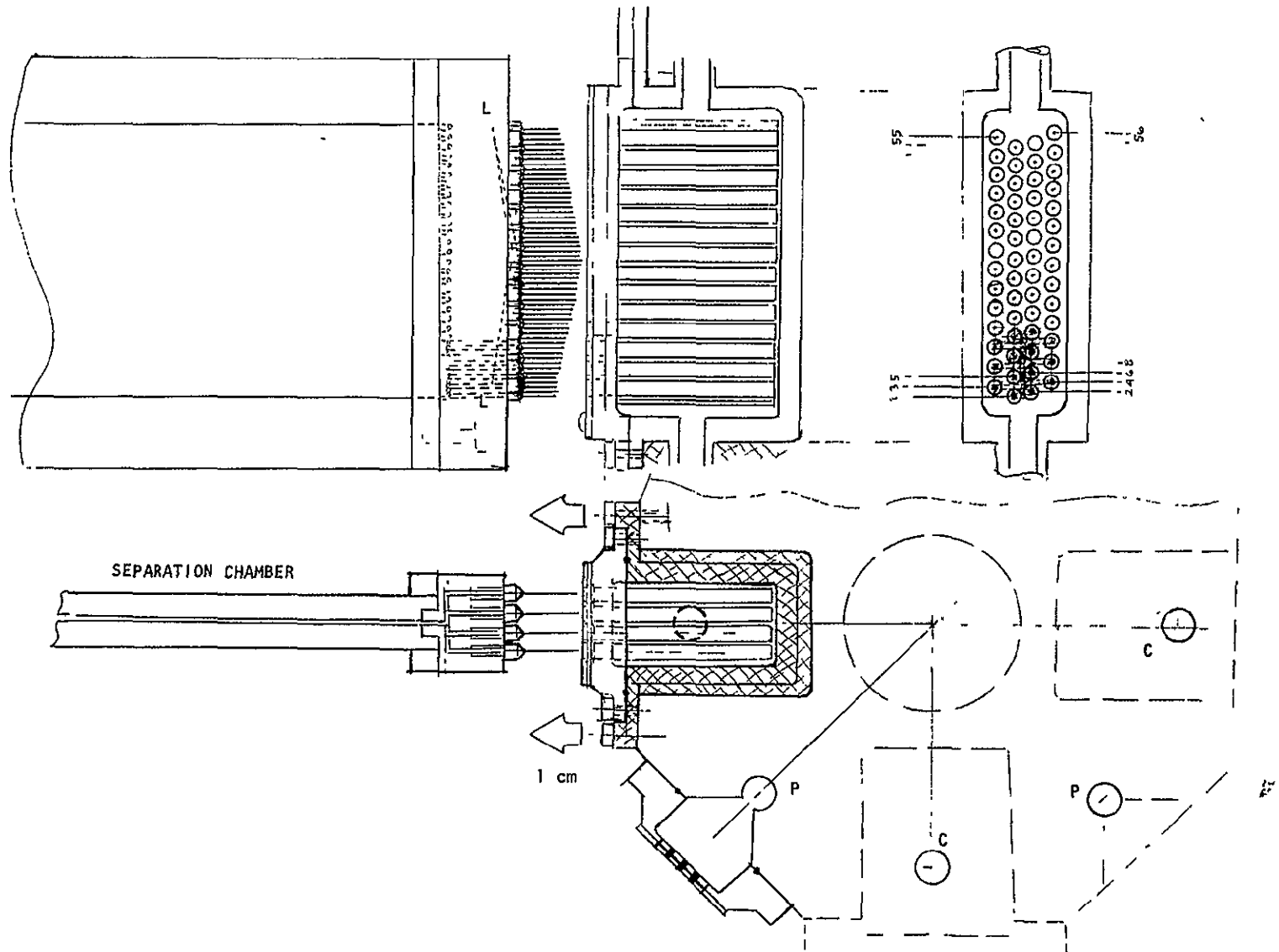


Figure C-4 Separation Chamber



The cross-hatched area indicates thermal insulation surrounding the vial coolant chambers to minimize the cooling load.

Each purge chamber is sealed by a rubber membrane, sandwiched between drilled plates, which is pierced by the hypodermic array.

External plumbing is not shown, but seems straightforward. The purge lines might all be pumped in parallel. If refrigeration is not desired during separation, the vial chamber coolant lines would have to be valved independently. If collapsible-type vials are used, the coolant flow must be at constant pressure (but not at constant volume) to accommodate the decrease in chamber volume as the vials are filled. Rotating fluid connections are not required. Since the drum makes less than one revolution, flexible coolant and drain lines can simply be brought out through the hollow shaft.

Figure C-5 represents a device that mechanically generates the sequence of linear and rotary motions using one drive motor and a limit switch.

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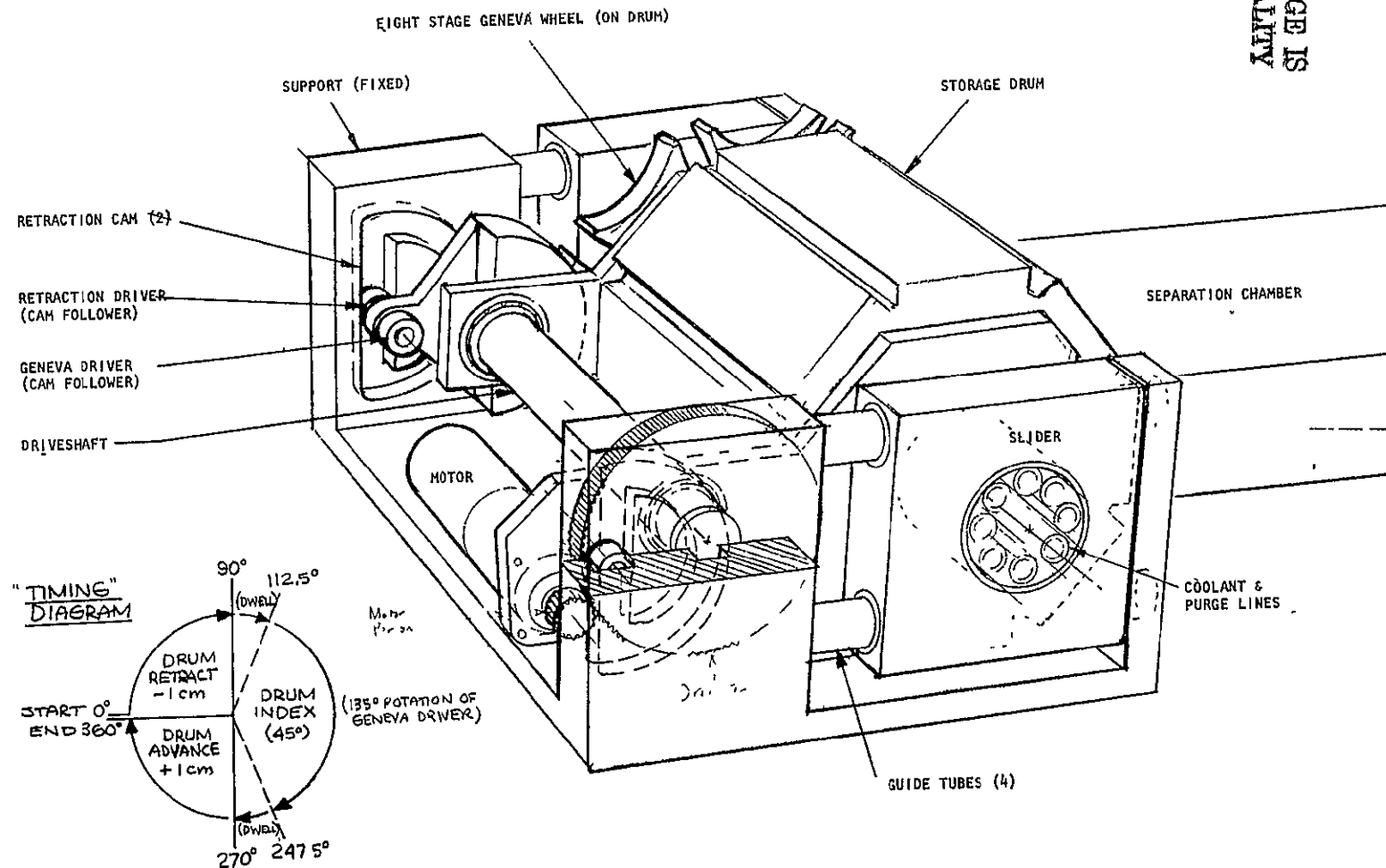


Figure C-5 Drum Actuation Mechanism

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## APPENDIX D

PRELIMINARY THERMAL EVALUATION OF ELECTROMAGNETIC  
LEVITATION FACILITIES L1, L2, AND L3

## D.1 INTRODUCTION

Preliminary thermal analyses have been performed to determine levitation coil temperatures, required coolant flow rates, and associated coolant pressure drops for the subject facilities. The three materials considered in the analysis are tungsten, beryllium, and zirconia, whose respective melting temperatures are 3,410; 1,284; and 2,715°C. The tungsten specimen was heated with an electron beam but the beryllium and zirconia specimens were induction-heated.

## D.2 SUMMARY

Results of the thermal evaluation conducted on Facilities L1, L2, and L3 are presented in Table D-1.

Table D-1  
Coolant Flow Requirements

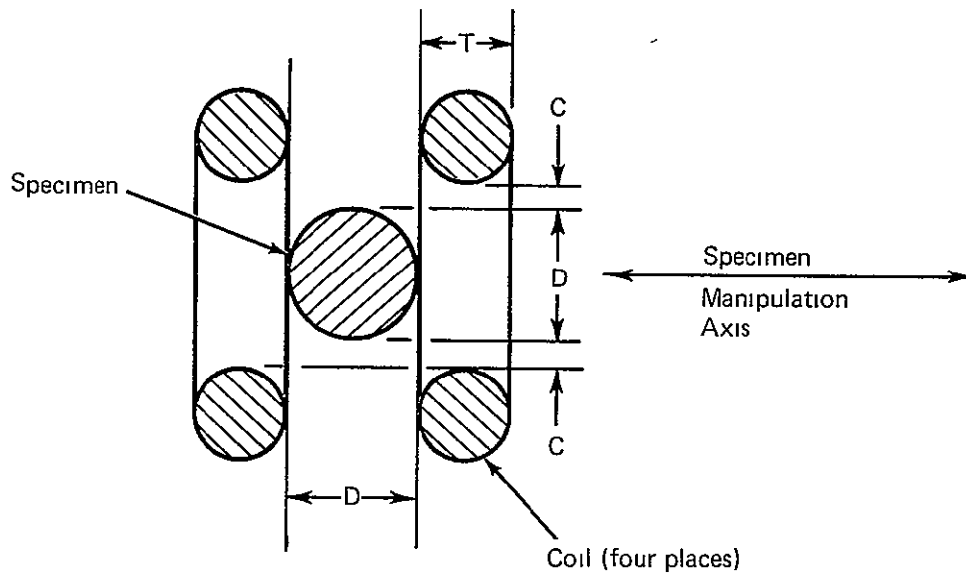
| Facility | Specimen  | Melting Temperature (°C) | Maximum Coil Temperature (°C) | Required Flow Rate (gpm) <sup>(a)</sup> | Pressure Loss (psi) |
|----------|-----------|--------------------------|-------------------------------|---|---------------------|
| L1       | Tungsten  | 3,410                    | 113                           | 2.0                                     | 0.771               |
| L2       | Beryllium | 1,284                    | 138                           | 3.0                                     | 0.159               |
| L3       | Zirconia  | 2,715                    | 138                           | 1.9                                     | 0.032               |

(a) Coolanol 20 (Monsanto) was assumed to be the heat transfer fluid circulated through the levitation coils.

The results indicate that the levitation coil temperatures can be limited to reasonable operating temperature levels without the use of excessive coolant flow rates and associated high-pressure losses.

## D.3 THERMAL ANALYSIS

The coil and specimen geometric relationships for each facility are shown in Figure D-1. A 0.20-cm clearance is provided to allow insertion and removal of the specimen without contacting the levitation coils. The inside tube diameter of the coil for the L1 Facility was assumed to be 0.25 in. (6.35 mm) since the specimen is heated by an electron beam. However, for L2 and L3, wherein the levitation coils also provided induction heating, the tube inside diameter was increased to 0.50 in. (12.7 mm) to manage the additional  $i^2R$  losses.



| Facility | Dimensions (cm) |      |      |
|----------|-----------------|------|------|
|          | D               | C    | T    |
| L1       | 1.00            | 0.20 | 0.94 |
| L2       | 2.00            | 0.20 | 1.57 |
| L3       | 1.00            | 0.20 | 1.57 |

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Figure D-1 Coil/Specimen Geometric Relationship

Infrared emittances of the tungsten, beryllium, and zirconia specimens at their melting temperatures were assumed to be 0.4, 0.4, and 0.5, respectively. The emittance of the coil exterior surfaces was considered to be identical to that of the specimen as a result of the deposition of specimen material. The chamber walls were held at approximately room temperature, using a liquid-coolant loop.

## D.4 RESULTS

Detailed thermal analysis results for each facility are presented in Table D-2. The maximum required coolant flow rate is 3.0 gpm for the L2 Facility levitation coil, which is only 15% efficient in providing induction heating of the beryllium specimen. The maximum coolant pressure loss occurs at the L1 levitation coil (tube diameter of 0.25 in.) and is 0.771 psi.

Table D-2  
Results of L1, L2, and L3 Facility Thermal Analysis

| Item | Description   | Facility   |           |          |
|------|---|------------|-----------|----------|
|      |   | L1         | L2        | L3       |
| 1    | Specimen material.                                  | Tungsten   | Beryllium | Zirconia |
| 2    | Specimen diameter (cm).                             | 1.0        | 2.0       | 1.0      |
| 3    | Melting temperature (°C).                           | 3,410      | 1,284     | 2,715    |
| 4    | Specimen radiated power at melting temperature (W). | 1,308      | 167       | 709      |
| 5    | Heat absorbed by coils from specimen (W).           | 540        | 54        | 349      |
| 6    | Heat absorbed by chamber from specimen (W).         | 768        | 113       | 360      |
| 7    | Coil $i^2R$ losses (W).                             | Negligible | 946       | 166      |
| 8    | Total heat absorbed by coil (W).                    | 540        | 1,000     | 515      |
| 9    | Power into coil (W).                                | Negligible | 1,113     | 875      |
| 10   | Coolant flow-rate (gpm).                            | 2.0        | 3.0       | 1.9      |
| 11   | Coolant inlet temperature (°C).                     | 38         | 38        | 38       |
| 12   | Coolant outlet temperature (°C).                    | 40         | 41        | 40       |
| 13   | Maximum levitation coil temperature (°C).           | 113        | 138       | 138      |
| 14   | Fluid pressure loss through levitation coils (psi). | 0.771      | 0.159     | 0.032    |

## D.5 CONCLUSIONS

This effort represents a preliminary thermal evaluation of the L1, L2, and L3 space processing facilities. Detailed thermal analysis is required before firm thermal design decisions can be made.

The results do indicate, however, that thermal control for the levitation coils which are subjected to high power dissipation densities can be achieved using conventional forced liquid-cooling techniques.

APPENDIX E

APPLICABLE INDUSTRIAL AUTOMATION EQUIPMENT

Equipment characteristics have been compiled in three basic mutually supporting formats:

- Format in which a number of manufacturers produce comparable equipment to implement a well-defined function. One representative hardware element is described in detail. An example of such an element is a thermocouple temperature sensor which is produced by a multitude of companies. The data sheet format used follows that developed in the "Requirements and Concepts for Materials Science and Manufacturing in Space (MS/MS) Study", Contract NAS 8-28938.
- Format in which a number of manufacturers produce comparable equipment to implement a well-defined function. A tabular comparison is made of the major characteristics of equipment of different manufacturers. This supplements the representative element data sheet described by showing the range of variation of major characteristics for the equipment of different manufacturers.
- Format in which specific hardware is not available to implement a function or in which the available hardware is deemed to have undesirable characteristics. Some alternative industrial automation techniques are discussed. An example of this is material transfer in which industrial equipment depends largely on gravity and devices such as conveyors or unwieldy robots. In this case, typical material transfer techniques are described.

## E.1 MATERIAL HANDLING EQUIPMENT

As a result of the widely varied nature of industrial products and processes, industrial automation material handling hardware consists primarily of special devices and systems designed for each manufacturing function. Some general purpose hardware devices are available, such as conveyors, parts feed mechanisms, and industrial robot systems; however, these devices are not directly applicable in the space environment. Most general-purpose devices depend on gravity to function so available devices are not directly usable, although some of the device concepts are usable. Figure E-1 illustrates simple examples of industrial material handling escapement concepts that have been modified to replace the force of gravity by spring force.

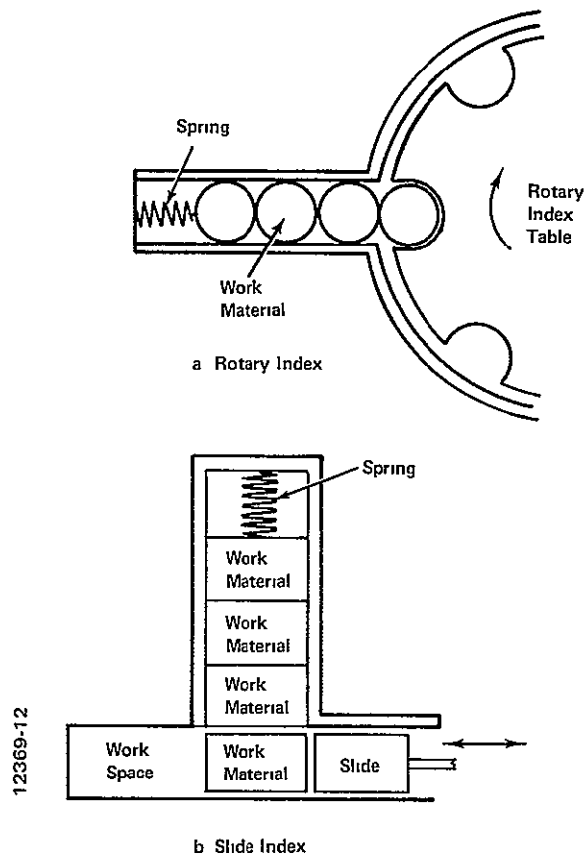


Figure E-1 Typical Material Handling Escapements

Most available industrial robot systems are not applicable in space because they are hydraulically or pneumatically actuated and, thereby, are not suitable for the space environment. Available electrically actuated robots would require extensive modifications, such as replacement of motors with brushless or sealed motors



and replacement of bearings with bearings designed for the space environment. In addition, industrial robots would require an exorbitant amount of volume in the space processing system because their general-purpose design makes them over-designed for the space processing system envisioned. The characteristics of representative electrically actuated industrial robots are shown in Table E-1 and in Commercial Item Survey Data Sheet 1.

Table E-1  
Robots

| Manufacturer   | Payload<br>(Pound) | Horizontal<br>Stroke<br>(Inch) | Horizontal<br>Swing<br>(Degree) | Vertical<br>Stroke<br>(Inch) | Wrist<br>Rotation<br>(Degree) | Actuator<br>Power | Programming<br>Method                |
|--|--------------------|--------------------------------|---------------------------------|------------------------------|-------------------------------|-------------------|--------------------------------------|
| Wickes Machine Tool Div.<br>515 N. Washington<br>Saginaw, Mich. 48607  | 100                | 0 to 42                        | 0 to 270                        | 0 to 60                      | 0 to 180                      | Electric          | Pinboard                             |
| Sunstrand Machine Tool<br>Belvidere, Ill. 61008                        | 25                 | 0 to 42                        | 0 to 330                        | 0 to 71                      | 0 to 360                      | Electric<br>Motor | Recording<br>Manually<br>Guided Path |
| Weiser/Robodyne Corp.<br>949 Bonifant St.<br>Silver Springs, Md. 20910 | 2                  | 0 to 4                         | 0 to 360                        | 0 to 6                       | 0 to 360                      | Servo-<br>motors  | Switch Panel                         |

COMMERCIAL ITEM SURVEY DATA SHEET 1

Candidate Commercial Item Description

Industrial robot for material transfer and placement operation requiring rectilinear motions.

Item Name

Transfer robot

Supplier

Weiser/Robodyne Corp.  
949 Bonifant St.  
Silver Springs, Md. 20910  
Phone (301) 588-6100

Model Number

Transfer Robot 200

Performance Specifications

Motions: Grips a part, lifts it straight up, transfers it in a straight line, lowers it, and releases it. Horizontal stroke, adjustable, 3 in. min; 10 in. max. Vertical stroke, adjustable, 3/8 in. min; 2 in. max.

Weight of parts, max 1/2 lb

Accuracy of placement,  $\pm 0.002$  in.

Cycles per minute, average 30

Programmable

Electric motor drive

Power source: 117 Vac, 60 Hz, 1 A

Weight, Transfer robot 36 lb  
Controller 8 lb

Size, Transfer robot 5 5/8 by 29 9/32 by 9 9/16 in.  
Controller 6 1/8 by 8 3/8 by 8 in.

Data Output

None

Power

110 W, 117 Vac, 60 Hz

COMMERCIAL ITEM SURVEY DATA SHEET 1 (CONT.)

Weight

44 lb total

Volume

Approximately 1 cu ft

Packaging/Mounting

Transfer robot and controller in separate packages as described above.

Modification for Space Application

Replace motors with sealed units and modify for conductive cooling.

Repackage controller for conductive cooling.

Shipping, Storing, and Handling Considerations

No special requirements.

Of the industrial automation material handling hardware investigated, two specific devices were identified which could be used in the space processing system with relatively minor modifications. They are the crystal pulling mechanism described in Commercial Item Survey Data, Sheet 2 and Figure E-2 and a boat pulling mechanism.

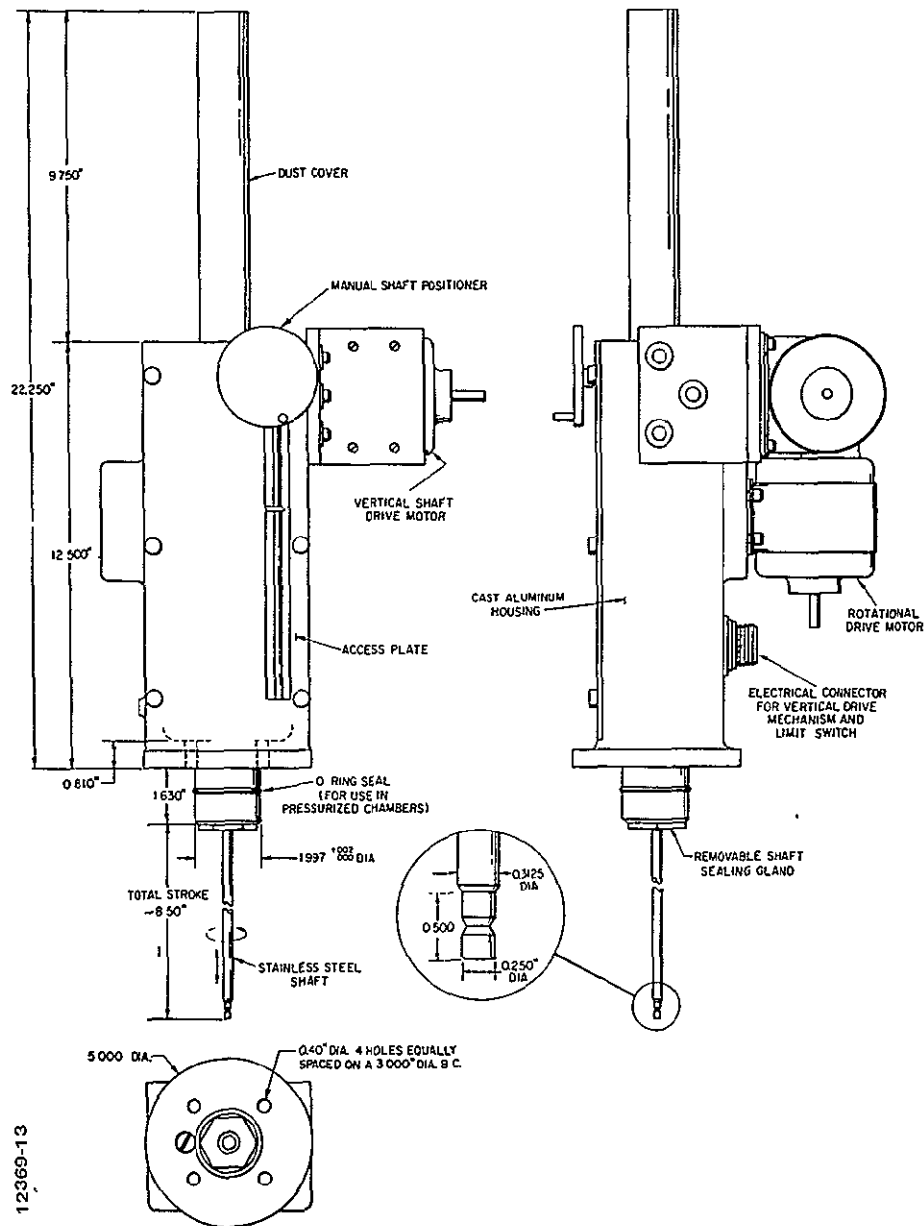


Figure E-2 ADL Crystal Withdrawal Mechanism

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COMMERCIAL ITEM SURVEY DATA SHEET 2

Candidate Commercial Item Description

Crystal puller, with translational and rotational drives for providing the motions required for withdrawal of the seed crystal in single-crystal growing production.

Item Name

ADL crystal withdrawal mechanism.

Supplier

Arthur D. Little, Inc.  
Acorn Park  
Cambridge, Mass. 02140  
Phone (617) 864-5770

Model Number

Catalog number 3637-035.

Performance Specifications

General Description

Cast aluminum frame.  
0.3125-in.-diameter stainless steel withdrawal shaft.  
Optional water-cooled withdrawal shaft.  
Rotational drive motor (variable-speed dc shunt-wound motor, Bodine NSH-12R).  
Vertical drive motor (variable-speed dc shunt-wound motor, Bodine NSH-12R).  
Manual positioner for rapid shaft-height adjustment.  
Upper and lower limit switches (interconnected with the vertical drive motor).  
Two Minarik Model SH-14 motor controls (each interwired with the rotational drive motor, vertical drive motor, and upper and lower limit switches).  
Removable shaft-sealing gland complete with O-ring and wiper rings.  
Seal effective at pressures ranging from  $10^{-5}$  Torr to 100 atmospheres.

Operating Characteristics

Total withdrawal distance, approximately 8.5 in.  
Rotational rate range (variable speed), 0 to 32 rpm.  
Withdrawal rate range (variable speed), 9.1 to 1.8 in. per hr.

COMMERCIAL ITEM SURVEY DATA SHEET 2 (CONT.)

Data Output

None.

Power

40 W, 115 Vdc.

Weight

15 Kg.

Volume

Approximately 2 cu ft.

Packaging/Mounting

Fabricated from an aluminum casting. All internal units (lead screw, bearings, etc.) are sealed by an access plate and dust cover so that corrosion or accumulation of abrasive dust particles cannot occur.

Modification for Space Applications

Replace the drive motors with brushless dc motors and replace the manual speed control with a computer or controller automatic speed control interface.

Shipping, Storing, and Handling Considerations

No special requirements.

It is, therefore, concluded that the industrial automation material handling hardware is not generally applicable to the space processing system, and special purpose hardware designs are necessary. These designs must consider and accommodate the space environment and the requirements of the space products and processes. Product and process requirement considerations include material environment, material characteristics, contamination control, and process characteristics. Product and process combinations may require raw material and product storage and processing conditions ranging over combinations of factors such as low, high, and/or closely controlled temperature. They may require an inert atmosphere, vacuum atmosphere, or special gas atmosphere, perhaps at a controlled pressure and temperature, or some other environment. At the same time, contamination control may be a critical process or product requirement and, thereby, an important design consideration.

## E.2 PROCESS AND ENVIRONMENT MEASUREMENT EQUIPMENT

Industrial equipments to make necessary measurements of process and environment temperature, pressure, vacuum, and gas constituents are available. These equipments are summarized in Tables E-2 through E-5 and Commercial Item Survey Data Sheets 3 through 11.

Table E-2

## Temperature Measurement Equipment

| Sensor Type         | Range (°C)   | Manufacturer and Model  |
|---------------------|--|---|
| Thermistor          | -100 to +300<br>to 150   | Omega Engineering Type UUA<br>Fenwall Electronics Type GA51<br>Yellow Springs Instrument Co. Type YSI   |
| Thermocouple        | 280 to 1100<br>10 to 2200<br>280 to 1100   | Bailey (Babcock and Wilcox) Type E51-7<br>Omega Type XTA W5R26-026-30-B-125-30-B<br>United Sensor and Control Type TA, TB, and TU                                       |
| Resistance          | -200 to +500<br>-100 to +800<br>750  | Bailey (Babcock and Wilcox) Type E51-5<br>Hy-Cal Engineering Type EL150 and 200<br>Omega Engineering Type PR11 and 12 Tylan   |
| Radiation Pyrometer | -20 to 2000<br>550 to 2200<br>30 to 3000<br>700 to 3000<br>600 to 3000<br>80 to 3000<br>1000 to 3400 | Aga Infrared Instruments Type THP-1<br>Bailey (Babcock and Wilcox) Type E51-4<br>Barnes Engineering Type IT-7<br>Type EP-1<br>Ircon Type 2000<br>Type 6000<br>Type 1100 |

Table E-3

## Pressure Measurement Equipment

| Sensor              | Range (psig)                                 | Manufacturer and Model   |
|---------------------|--|--|
| Bourdon Tube        | 0 to 30; 0 to 8000                           | Bailey (Babcock and Wilcox) Type KP12                                  |
| Solid State         | 0 to 10; 0 to 1500<br>0.01 to 100; 1 to 5000 | Bailey (Babcock and Wilcox) Type KQ<br>PCB Piezotronics, Inc. Type 100 |
| Variable Reluctance | 0 to 0.1 psia<br>0 to 1000 psia              | Validyne Engineering; AP10   |



Table E-4

## Vacuum Pressure Measuring Equipment

| Manufacturer                   | Model                    | Type   | Ranges<br>(Torr)  | Size<br>(Inch)             | Weight<br>(lb)          |
|--------------------------------|--------------------------|--|---|----------------------------|-------------------------|
| Cooke Vacuum<br>Products, Inc. | R1GC-72                  | Ionization<br>(radiation and<br>hot wire)                | 760 to $10^{-9}$<br>(12 ranges)                                     | 8 by 20 5/8 by 11 1/4      | 19                      |
|                                | CC-UHV                   | Cold cathode<br>(CC4 tube)                               | $10^{-4}$ to $10^{-13}$   | 5 1/4 by 19 by 8           | 17 plus tube<br>(26 oz) |
|                                | TG62                     | Thermocouple   | 1000 to 1 microns   | 19-inch rack-mount         | 15                      |
| Edwards High<br>Vacuum, Inc.   | 5M                       | Ionization<br>(hot wire)                                 | $10^{-4}$ to $10^{-11}$   | 10 1/8 by 19 3/8 by 13 5/8 | 49                      |
| Perkin-Elmer<br>Ultek Div.     | Digital<br>Ion Gauge     | Ionization<br>(hot wire)                                 | $1 \times 10^{-2}$ to $2 \times 10^{-12}$                           | 14 by 19 by 3 1/2          | 15                      |
| Varian<br>Associates           | Dual Range<br>Ionization | Ionization   | $0.6 - 1 \times 10^{-6}$<br>$10^{-3}$ to $10^{-12}$                 | 3 1/2 by 19 by 15          | 17                      |
|                                | NRC 840                  | Thermocouple<br>Ionization                               | 2 to $1 \times 10^{-3}$<br>$1 \times 10^{-3}$ to $2 \times 10^{-9}$ | 3 1/2 by 19 by 11          | 12                      |
|                                | NRC 855                  | Cold cathode<br>(NRC 524-2)                              | $5 \times 10^{-3}$ to $1 \times 10^{-9}$                            | 8 1/4 by 5 7/16 by 6 3/4   | 6                       |
|                                | NRC 856                  | Thermocouple<br>(NRC 531)<br>Cold cathode<br>(NRC 524-2) | 2 to $1 \times 10^{-9}$   | 8 1/4 by 5 7/16 by 6 3/4   | 8                       |

Table E-5  
Gas Analyzer

| Manufacturer                                     | Model                | Type                             | Gas   | Speed                           | Output  | Size (inch)                         | Weight (lb) |
|--|----------------------|----------------------------------|---|---------------------------------|---|-------------------------------------|-------------|
| Beckman Instrument, Inc                          | 864                  | Infrared                         | CO/CO <sub>2</sub><br>SO <sub>2</sub> , NH <sub>3</sub> | 0 5/2 5 sec                     | 0 to 10, 0 to 150m Vdc<br>0 to 1, 0 to 5 Vdc<br>4 to 20, 10 to 50 mA              | 13 by 8 3/4 by 22 5                 | 35          |
|  | 741                  | Polarographic                    | O <sub>2</sub>  | 20 sec                          | as above  |                                     | 25          |
| Bendix Scientific Instruments and Equipment Div. | MA3                  | Time-of-flight mass spectrometer | Up to 600 AMU   | 30,000 spectra per sec          | Digital on strip chart  |                                     |             |
| Honeywell Systems and Research                   | MGA                  | Mass spectrometer                | Four tunable channels<br>0 to 300 AMU                   |                                 |   |                                     |             |
| Leeds and Northup                                | 7803                 | Thermomagnetic                   | O <sub>2</sub>  | 15 sec time constant<br>10 sec  | 0 to 5 mV dc<br>0 to 10, 0 to 100 mVdc  | 11 5 by 9 5 by 17 5<br>8 by 14 by 8 | 48          |
| Mine Safety Appliance                            | Billion Ave Portable | Ionization                       | Depends on reagent used                                 |                                 |   |                                     |             |
|  | Lira 202FR           | Infrared Luft-type               | CO/CO <sub>2</sub>                                      | 0 4 to 1 5 sec                  | 0 to 10, 0 to 100 mV<br>0 to 1, 0 to 5, 0 to 10 Vdc<br>0 to 50 mA in seven ranges | 19 by 13 by 12 5                    | 76          |
| Uthe Technology International                    | 100B                 | Quadrupole mass spectrometer     | Single peak monitoring<br>0 to 250 AMU                  | Scans from 75 msec to 2 minutes | 0 to 10 V for ion current and mass numbers  |                                     | 75          |
| Veeco  | SPI-10               | Monopole mass spectrometer       | Single peak monitoring<br>0 to 250 AMU                  | Variable 3 msec to 300 sec      | Oscilloscope  | 15 by 7 by 19 3/4<br>4 5 by 21 5    | 79 5        |

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COMMERCIAL ITEM SURVEY DATA SHEET 3

Candidate Commercial Item Description

Thermistor for use in contact temperature measurement and control.

Item Name

Iso-curve.

Supplier

Fenwal Electronics, Inc.  
63 Fountain St.  
Framingham, Mass.  
Phone (617) 875-1351

Model Number

GA through GD.

Performance Specification

Temperature range -100 to +350°C.  
Interchangeability and repeatability  $\pm 0.2^\circ\text{C}$ .  
Temperature coefficient approximately  $10 \times 10^{-3}$  ohm per ohm per °C.

Data Output

Resistance value change.

Power

Negligible.

Weight

Variable (less than 30 g).

Volume

Variable.

Packaging/Mounting

Mounted at or near experiment package.

Cost

Approximately \$110.

Modifications for Zero-G Performance or Space Applications

None.

COMMERCIAL ITEM SURVEY DATA SHEET 3 (CONT.)

Shipping, Storage, and Handling Considerations

None.

Additional Comments

Recommended for use in vacuum or inert environments only, when using Type U (insulated tantalum sheath) junction.

COMMERCIAL ITEM SURVEY DATA SHEET 4

Candidate Commercial Item Description

Thermocouple for use in contact temperature measurement.

Name

Thermocouple probe.

Supplier

Omega Engineering, Inc.  
Box 4047 Springdale Station  
Stamford, Conn. 06907  
Phone (203) 359-1660

Model

XTA-W5R26-062-30B.  
XTA-W5R26-125-30-B.

Performance Specifications

Temperature range, up to 2300°C.  
Interchangeability and repeatability,  $\pm 5^{\circ}\text{C}$  or  $\pm 1\%$  of temperature as defined in standard reference tables (adopted 23 Nov 1965).  
Temperature coefficient,  $2 \times 10^{-2}$  mV per  $^{\circ}\text{C}$  average.

Data Output

0 to 40 mVdc signal.

Power

None.

Weight

Variable.

Volume

Variable.

Packaging/Mounting

Mounted on or near experiment package by bonding.

COMMERCIAL ITEM SURVEY DATA SHEET 4 (CONT.)

Modifications Required for Zero-G Performance and Space Applications

None.

Shipping, Storage, and Handling Considerations

None.

Additional Comments

None.

COMMERCIAL ITEM SURVEY DATA SHEET 5

Candidate Commercial Item Description

Resistance thermometer for use in contact temperature measurement and control.

Name

Platinum resistance temperature elements.

Supplier

Omega Engineering, Inc.  
Box 4047, Springdale Station  
Stamford, Conn. 06907  
Phone (203) 359-1660

Model Number

Type PR-11.

Performance Specifications

Nominal resistance, 100 ohms at 0°C (200 and 500 ohms also available).  
Alpha temperature coefficient, 0.00392 ohms per ohm per °C.  
Sensitive material, platinum, reference grades.  
Temperature range, -100 to +750°C.  
Interchangeability,  $\pm 0.25^\circ\text{C}$ , at 0°C.  
Long term stability, drift  $< \pm 0.05^\circ\text{C}$ .  
Response time, in 0.25-in.-diameter sheath immersed in water flowing at 3 ft per sec, response time to 63% of a step change in temperature is less than 5.0 sec.

Data Output

Resistance values.

Power

None.

Weight

Variable.

Volume

Variable (Standard 100 ohm unit, sensing element diameter 0.09 in., length 0.28 in.).

COMMERCIAL ITEM SURVEY DATA SHEET 5 (CONT.)

Packaging/Mounting

Mounted on or near experiment package.

Cost

\$40 to \$45.

Modifications for Zero-G Performance, Safety, Reliability, etc.

None.

Shipping, Storage, and Handling Considerations

None.

Additional Comments

Will be used with either an indicating or non-indicating controller, or may be read out on a modified digital voltmeter.



COMMERCIAL ITEM SURVEY DATA SHEET 6

Candidate Commercial Item Description

Infrared pyrometer for use in noncontact temperature measurement and control.

Name

Modline.

Supplier

Ircon  
207 Lawrencewood Center  
Niles, Illinois 60648  
Phone (312) 967-5151

Model Number

2000 series.

Performance Specifications

Temperature ranges, 40 to 3,000 °C (104 to 5,400 °F) dependent on head and indicator.

Spectral response, 0.70 to 0.97  $\mu\text{m}$ .

Calibration accuracy,  $\pm 1\%$  full-scale temperature or  $\pm 5^\circ\text{C}$  ( $\pm 10^\circ\text{F}$ ), whichever is greater.

Repeatability,  $\pm 0.3\%$  full-scale temperature.

Response time at meters, 95% full-scale input within 1 sec.

Indicator/controller ambient temperature range, 10 to 65 °C (50 to 150 °F).

Sensing head ambient temperature range, -32 to 94 °C (0 to 200 °F).

Data Output

0 to 100 mV dc (100  $\Omega$  source) plus a variety of other outputs.

Power

15 W maximum (115/230 V  $\pm 10\%$ , 50/60 Hz).

Weight

Head, 7 kg (15 lb).

Volume

Head, 6,750  $\text{cm}^3$  (435  $\text{in.}^3$ ).

Indicator/controller, 13,500  $\text{cm}^2$  (870  $\text{in.}^3$ ).

COMMERCIAL ITEM SURVEY DATA SHEET 6 (CONT.)

Packaging/Mounting

Head bolted near or on experiment enclosure controller; rack mount.

Cost

With digital display without control, \$1,800.

With three-mode proportional control and deviation meter, \$2,400.

Modifications for Zero-G Performance, Safety, Reliability, etc.

Forced cooling.

Shipping, Storage, and Handling Considerations

None.

Additional Comments

Electronics may be modified to produce a wide range of temperature measurements on the same instrument.

COMMERCIAL ITEM SURVEY DATA SHEET 7

Candidate Commercial Item Description

Pressure transducer for use in measuring gaseous or liquid supply pressures.

Item Name

Pressure transducer.

Supplier

PCB Piezotronics, Inc.  
Box 33, Buffalo, New York 14225  
Phone (716) 684-0001

Model Number

Series 100.

Performance Specification

See Figure E-3.

Data Output

DC mV signal proportional to initial or average level.

Power

Up to 20 mA from 18 to 24 V supply.

Weight

Variable.

Volume

Variable.

Packaging/Mounting

Mounted at or near experiment.

Cost

Up to \$300.

Modifications Required for Zero-G Space Applications

None.

Shipping, Storage, and Handling Considerations

None.

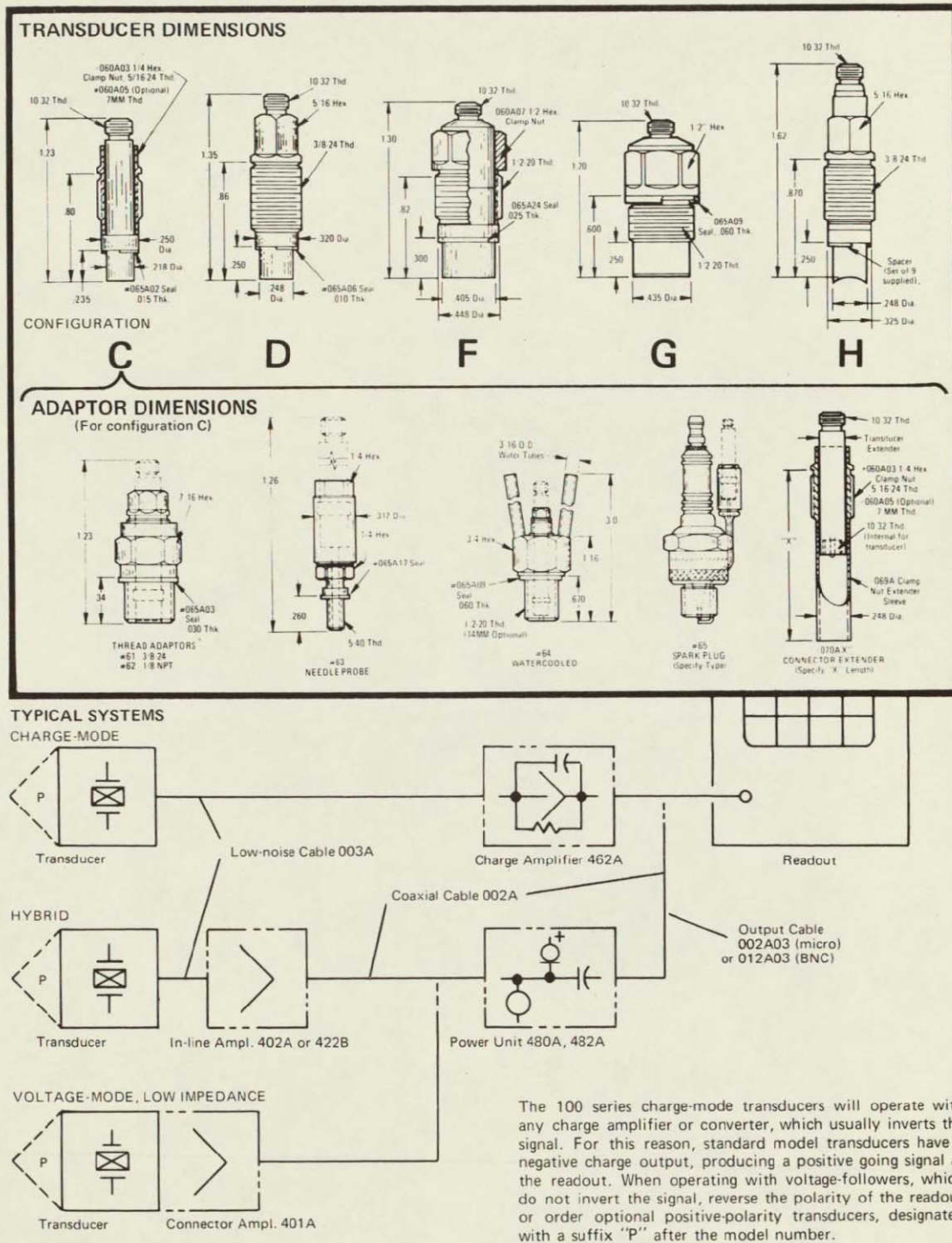
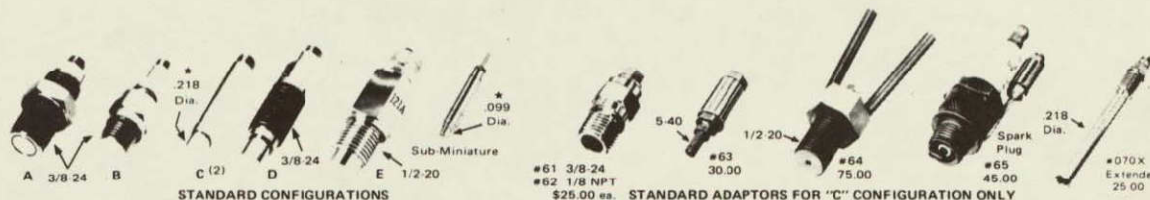


Figure E-3 Pressure Transducer Characteristics (Sheet 1 of 2)

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QUARTZ, VOLTAGE-MODE, LOW-IMPEDANCE  
PRESSURE TRANSDUCERS  
with built-in amplifiers<sup>(3)</sup> Series 100



| DYNAMIC RANGE <sup>(1)</sup>             | psi    | .01 to 100       |                  |                         |                     | .2 to 1000       |                         | 1 to 5000        |                         | 2 to 10,000      |                         |                       | 10 to 80,000<br>(Special to 120,000) |                         |
|--|--------|------------------|------------------|-------------------------|---------------------|------------------|-------------------------|------------------|-------------------------|------------------|-------------------------|-----------------------|--------------------------------------|-------------------------|
| Application                              |        | General Purpose  | High Resolution  | High Frequency          | Industrial OEM      | General Purpose  | High Frequency          | General Purpose  | High Frequency          | General Purpose  | High Frequency          | Hydraulic Pump        | Ballistics                           | High Frequency          |
| Frequency Tailored <sup>(5)</sup>        |        |                  |                  | ★                       |                     |                  | ★                       |                  | ★                       |                  | ★                       |                       |                                      | ★                       |
| Acceleration Compensated                 |        |                  |                  |                         |                     |                  |                         |                  |                         |                  |                         |                       |                                      |                         |
| Ground Isolated (A & B Configurations)   |        |                  |                  |                         |                     |                  |                         |                  |                         |                  |                         |                       |                                      |                         |
| Standardized Sensitivity (± 5%)          |        |                  |                  |                         |                     |                  |                         |                  |                         |                  |                         |                       |                                      |                         |
| Static Calibration                       |        |                  |                  |                         |                     |                  |                         |                  |                         |                  |                         |                       |                                      |                         |
| MODEL NO. Config. A                      | Price  | 101A<br>240.00   | 102A02<br>350.00 | 102A12<br>430.00        |                     |                  |                         |                  |                         |                  |                         |                       |                                      |                         |
| MODEL NO. Config. B                      | Price  | 101A05<br>240.00 | 102A05<br>350.00 | 102A15<br>430.00        |                     | 101A04<br>280.00 | 102A04<br>430.00        | 101A02<br>280.00 | 102A<br>430.00          | 101A03<br>300.00 | 102A03<br>460.00        |                       |                                      |                         |
| MODEL NO. Config. C <sup>(2)</sup>       | Price  | 111A21<br>240.00 | 112A21<br>280.00 | 113A21<br>410.00        |                     | 111A24<br>260.00 | 113A24<br>410.00        | 111A22<br>260.00 | 113A22<br>410.00        | 111A23<br>280.00 | 113A23<br>430.00        |                       |                                      |                         |
| MODEL NO. Config. D or E                 | Price  |                  |                  |                         | 121A (E)<br>150.00  |                  |                         |                  |                         |                  |                         | 108A02(D)<br>350.00   | 108A (D)<br>450.00                   | 109A (D)<br>525.00      |
| SENSITIVITY                              | mV/psi | 40 ± 10          | 50 ± 10          | 20 ± 4                  | 40 ± 20             | 5 ± 5            | 5 ± 25                  | 1 ± 1            | 1 ± .05                 | .5 ± .05         | .5 ± .03                | .5                    | .1                                   | .1                      |
| Resolution<br>(200 μV P.P. Elect. Noise) | psi    | .005             | .004 *           | .01                     | .005                | .04              | .04                     | .2               | .2                      | .4               | .4                      | .4                    | 2                                    | 2                       |
| Resonant Frequency                       | Hz     | 300,000          | 250,000          | 500,000 <sup>(15)</sup> | 200,000             | 400,000          | 500,000 <sup>(15)</sup> | 400,000          | 500,000 <sup>(15)</sup> | 400,000          | 500,000 <sup>(15)</sup> | 300,000               | 300,000                              | 500,000 <sup>(15)</sup> |
| Rise Time                                | μsec   | 2                | 2                | 1 *                     | 3                   | 1                | 1 *                     | 1                | 1 *                     | 1                | 1 *                     | 2                     | 2                                    | 1 *                     |
| Time Constant <sup>(6)</sup>             | sec    | 1                | 1                | 1                       | 1                   | 100              | 100                     | 500              | 500                     | 1000             | 1000                    | 1000                  | 2000                                 | 2000                    |
| Low Frequency (5% down) <sup>(6)</sup>   | Hz     | .5               | .5               | .5                      | .5                  | .005             | .005                    | .001             | .001                    | .0005            | .0005                   | .0005                 | .0003                                | .0003                   |
| Linearity <sup>(7)</sup>                 | %      | 1                | 1                | 1                       | 2                   | 2                | 1                       | 2                | 1                       | 2                | 1                       | 2                     | 2                                    | 2                       |
| Range (for 5 volts out)                  | psi    | 125              | 100              | 250                     | 125 <sup>(11)</sup> | 1000             | 1000                    | 5000             | 5000                    | 10,000           | 10,000                  | 10,000                | 50,000                               | 50,000                  |
| Range (for 10 volts out) <sup>(4)</sup>  | psi    | 250              | 200              | 500                     | 250                 | 2000             | 2000                    | 10,000           | 10,000                  | 20,000           | 20,000                  | 20,000                | 100,000                              | 100,000                 |
| Maximum Pressure                         | psi    | 1000             | 1000             | 1000                    | 1000                | 10,000           | 10,000                  | 15,000           | 15,000                  | 20,000           | 20,000                  | 20,000                | 125,000                              | 125,000                 |
| Output Impedance                         | <ohms  | 100 *            | 100 *            | 100 *                   | 100 *               | 100 *            | 100 *                   | 100 *            | 100 *                   | 100 *            | 100 *                   | 100 *                 | 100 *                                | 100 *                   |
| Vibration/Shock <sup>(8)</sup>           | g      | 2000/20,000      | 2000/20,000      | 2000/20,000             | 2000/20,000         | 2000/20,000      | 2000/20,000             | 2000/20,000      | 2000/20,000             | 2000/20,000      | 2000/20,000             | 2000/20,000           | 2000/20,000                          | 2000/20,000             |
| Acceleration Sensitivity                 | psi/g  | .01              | .002 *           | .002 *                  | .02                 | .002 *           | .002 *                  | .002 *           | .002 *                  | .002 *           | .002 *                  | .01                   | .01                                  | .004                    |
| Temperature Range <sup>(10)</sup>        | °F     | -100 + 275       | -100 + 275       | -100 + 275              | -100 + 275          | -100 + 275       | -100 + 275              | -100 + 275       | -100 + 275              | -100 + 275       | -100 + 275              | -100 + 275            | -100 + 275                           | -100 + 275              |
| Temperature Coefficient                  | %/°F   | .03              | .03              | .03                     | .04                 | .03              | .03                     | .03              | .03                     | .03              | .03                     | .03                   | .03                                  | .03                     |
| Flash Temperature                        | °F     | 3000             | 3000             | 3000                    | 3000                | 3000             | 3000                    | 3000             | 3000                    | 3000             | 3000                    | 3000                  | 3000                                 | 3000                    |
| Case Material <sup>(12)</sup>            | SS     | 17-4PH           | 17-4PH           | 17-4PH                  | 303                 | 17-4PH           | 17-4PH                  | 17-4PH           | 17-4PH                  | 17-4PH           | 17-4PH                  | 18-300                | 18-300                               | 18-300                  |
| Diaphragm Material <sup>(12)</sup>       | Invar  | Invar            | Invar            | Invar                   | 303 <sup>(9)</sup>  | Invar            | Invar                   | Invar            | Invar                   | Invar            | Invar                   | 18-300 <sup>(9)</sup> | 18-300 <sup>(9)</sup>                | 18-300 <sup>(9)</sup>   |
| Connector                                |        | 10-32            | 10-32            | 10-32                   | TNC                 | 10-32            | 10-32                   | 10-32            | 10-32                   | 10-32            | 10-32                   | 10-32                 | 10-32                                | 10-32                   |

NOTES: (★ denotes exceptional characteristic)

- (1) Measures relative to initial or average level - Measures to full vacuum - Dynamic range 5000:1 independent of cable length.  
(2) Installs interchangeably with .218 dia. quartz minigages. 5/16-24 clamp nut is standard; 7 mm installation available.  
(3) Power required 2 to 20 ma thru cc diode from +18 to +24V DC supply for ± 5 volts output. Higher current drives long cables (>100 ft.).

- (4) +24V DC supply required for ± 10V DC output.  
(5) Near non-resonant response - suppressed ringing.  
(6) Measures transients lasting a few % of time constant.  
(7) % F.S. any calibrated range - zero based best straight line.  
(8) Built-in amplifier withstands 100,000 g shock.  
(9) Diaphragms are integral.

- (10) Special models operate from -440°F to +325°F.  
(11) Other ranges available.  
(12) Special diaphragm or case material available.

Options include other time constants, sensitivities, and configurations; signal conditioning, conformal diaphragm, ablative coating and welded hermetic sealing.

Figure E-3 Pressure Transducer Characteristics (Sheet 2 of 2)

COMMERCIAL ITEM SURVEY DATA SHEET 8

Candidate Commercial Item Description

Pressure transducers for use in measuring gaseous or liquid supply pressures.

Item Name

Variable reluctance pressure transducer.

Supplier

Validyne Engineering Corp.  
18819 Napa St.  
Northridge, Calif. 91324  
Phone (213) 886-8488

Model

AP 10.

Performance Specification

Pressure range, 0 to 0.1 psia, 0 to 1,000 psia.  
Linearity,  $\pm 1/2\%$  best straight line.  
Hysteresis,  $1/2\%$  pressure excursion.  
Temperature range, -65 to 250°F operating. 0 to 160°F compensated.

Data Output

50 mV per V full scale nominal.

Power

10 V input at 3,000 Hz.

Weight

11 ounces.

Volume

1.5 by 1 1/2 by 2 in.

Packaging/Mounting

Mounted at or near experiment.

Cost

Up to \$475.

Modifications Required for Zero-G and Space Applications

None.

Shipping, Storage, and Handling Considerations

None.

COMMERCIAL ITEM SURVEY DATA SHEET 9

Candidate Commercial Item Description

Vacuum gauge for measuring experiment chamber pressure.

Item Name

Vacuum control.

Supplier

Varian Associates, NRC Operations  
160 Charlemont St.  
Newton, Mass. 02161  
Phone (617) 332-5850

Model

Model 856, NRC 524-2, NRC 531

Performance Specification

Range,  $1 \times 10^{-9}$  to 2 Torr.  
Repeatability,  $\pm 3\%$  of meter arc.  
Line voltage dependency,  $\pm 3\%$  of meter arc (98 to 130 V).

Data Output

0 to 10 mV signal.

Power

3 W, 115/230 V, 50/60 Hz.

Weight

8 lb.

Volume

8.25 in. wide, 5 7/16 in. high, and 6.75 in. deep.

Packaging/Mounting

May be mounted up to 10 ft from sensor (gauge or thermocouple).

Cost

Control unit \$465, gauge \$155, thermocouple tube \$17 each.

Modifications Required for Zero G Space Applications

May require thermal modification.

Shipping, Storage, and Handling Considerations

None.

COMMERCIAL SURVEY DATA SHEET 10

Candidate Commercial Item Description

Vacuum gauge for measuring experiment chamber pressure.

Item Name

Millitorr vacuum ionization gauge.

Supplier

Varian Associates  
Vacuum Division  
611 Hansen Way  
Palo Alto, California 94303

Model

Model 971-5009.

Performance Specification

Pressure Range, 0.6 Torr to  $1 \times 10^{-6}$  Torr.

Emission Current, 5 to 15  $\mu\text{A}$

Characteristics, pressure in Torr =  $10^{-5}$  x collector current.

Sensitivity,  $S = \frac{\text{Collector current}}{\text{Grid current} \times \text{Pressure}} = 0.5 (\text{Torr})^{-1}$ .

Data Output

300 mV increases 300 mV for each decade to 1,000 mV.

Power

180 W, 120/240 Vac, 50/60 Hz, 1.5 A.

Weight

Control unit, 17 lb.  
Gauge 3.25 lb.

Volume

Control unit, 3.5 by 19 by 15 in.  
Gauge, 1 5/16 in. diameter by 6.25 in. long (mounted on 2.75 in. OD flange).

Packaging/Mounting

Gauge may be mounted up to 12 ft from control unit.



COMMERCIAL SURVEY DATA SHEET 10 (CONT.)

Cost

Gauge \$190.

Control unit \$850.

Cables \$85.

Modifications Required for Zero-G, Space Applications Thermal Control

Repackage electronics.

Shipping, Storage, and Handling Considerations

None.

COMMERCIAL ITEM SURVEY DATA SHEET 11

Candidate Commercial Item Description

Residual gas analyzer.

Name

Precision Gas Analyzer.

Supplier

Uthe Technology International  
320 Soquel Way  
Sunnyvale, California 94086  
Telephone (408) 738-3301

Model

Model 100B.

Performance Specifications

Mass Range, 1 to 250 AMU.  
Resolution, 500 at 250 AMU.  $M/\Delta M = 2M$  ( $\Delta M$  is peak width at one-half of peak height).  
Sensitivity,  $10^{-3}$  A per Torr for  $N_2$  for Faraday collector and 300 A per Torr with multiplier.  
Stability, peak height ratios  $\pm 0.5\%$ . Peak location  $\pm 0.02$  AMU.  
Speed, scans controllable from 75 msec to 2 min.  
Maximum operating pressure,  $10^{-3}$  Torr.  
Minimum partial pressure,  $10^{-14}$  Torr or 0.1 ppm, whichever is greater.

Data Output

0 to 10 V ion current signal.  
0 to 10 V mass number signal.

Power

110 to 125 Vac, 3 A, 60 Hz.

Weight

75 lb.

Volume

Sensor, 1.9-in.-diameter by 12 in. long.  
Electronics, 12 by 19 by 15 in.

COMMERCIAL ITEM SURVEY DATA SHEET 11 (CONT.)

Packaging/Mounting

Probe is mounted on Varian "Conflat" flange 4.5 in. OD.

Cost

\$10,000.

Modifications for Zero-G Performance, Safety, Reliability, etc.

Repackage electronics.

Shipping, Storage, and Handling Considerations

None.

Additional Comments

Maximum operating temperature, 180°C.

Bakeout to 400°C.

### E.3 PROCESS AND ENVIRONMENT CONTROL EQUIPMENT

A wide variety of industrial process and environment control equipment is available for consideration in support of space processing systems. Candidate equipment can be grouped into categories of (1) sensor-dedicated controllers, (2) relay controllers, (3) programmable controllers, and (4) minicomputers.

Sensor-dedicated controllers respond to inputs from a single sensor and control a process to some pre-determined set point, sequence, or operating profile. A furnace temperature controller can be such a unit, taking input from a temperature sensor and controlling the furnace heater to maintain a desired temperature. Typical sensor dedicated controllers are summarized in Table E-6. Characteristics of a typical set point controller are shown in Commercial Item Survey Data Sheet 12.

Table E-6  
Sensor Dedicated Controllers

| Controller    | Model  | Set Point                 |                           | Sample Rate        | Remote Control |
|---------------|--------|---------------------------|---------------------------|--------------------|----------------|
|               |        | Input                     | Output                    |                    |                |
| Dahl          | C601B  | 1 to 5, 4 to 20, 10 to 50 | 1 to 5, 4 to 20, 12 to 50 | 3 to 450 per min   | X              |
|               | C602B  | 1 to 5, 4 to 20, 10 to 50 | AC motor                  | 3 to 450 per min   | X              |
| Research, Inc | 624A   | Millivolts                | 30, 60, and 150 A         | 0.02 to 30 per min | X              |
|               | 640    | 1 to 5, 4 to 20, 10 to 50 | Multiple to 3.6 kW        | 0.1 to 10 per min  | X              |
|               | TO5192 | Millivolts                | 0 to 5 V, 0 to $\pm 5$ mA |                    | X              |
| Honeywell     | R7355  | Millivolts                | 4 to 20 mA                | 0.1 to 10 per min  |                |
| Omega         | 49, 50 | Millivolt                 | 10A at 120 V              |                    |                |

| Controller           | Sequence | Load                       | Program    |
|----------------------|----------|----------------------------|------------|
| Midwest Controls Co. | 12-24    | 24 and 250 VA<br>4 A Triac | Card diode |

Relay controllers can provide sequencing, on-off proportional control, and logical operation of processes. They are mentioned here but not described in a table because they are largely being superseded by solid-state programmable controllers.

COMMERCIAL ITEM SURVEY DATA SHEET 12

Candidate Commercial Item Description

Set point controller for use in process control.

Name

Process Controller.

Supplier

G. W. Dahl Co., Inc.  
86 Tupelo St.  
Bristol, Rhode Island 02809  
Phone (401) 253-9500

Model

C601B.

Performance Specification

Signal input, 1 to 5 mA dc.  
4 to 20 mA dc.  
10 to 50 mA dc.  
Other inputs available at factory.  
Output, 1 to 5 mA, 0 to 9 k-ohm load.  
4 to 20 mA, 0 to 2.2 k-ohm load.  
10 to 50 mA, 0 to 900 ohm load.  
Dead band control, Adjustable 0 to  $\pm 15\%$  of process span.  
Rate, Adjustable 0 to 250 sec.  
Reset, Adjustable 3 to 450 samples per min.

Data Output

Control signal.

Power

105 to 130 Vac, 50/60 Hz, 33 VA maximum.

Weight

11 lb.

Volume

20.75 by 6-5/8 by 3.25 in.

COMMERCIAL ITEM SURVEY DATA SHEET 12 (CONT.)

Packaging/Mounting

Aluminum slide-out case.

Cost

\$694. (one to four units)

Modifications for Zero-G Performance and Space Applications

May need some modification for thermal and vibration environments.

Shipping, Storage, and Handling Considerations

None.

Additional Comments

Set point may be remotely controlled.

Programmable solid state controllers can also perform sequencing, on-off proportional control, and logical operation of processes. Their principal advantages over relay controllers are (1) their programmability, which permits the flexibility of control changes, (2) their greater reliability, and (3) their smaller power requirements. Representative programmable controllers are shown in Table E-7. Characteristics of a typical programmable controller are shown in Commercial Item Survey Data Sheet 13.

Minicomputers are the most versatile of the process and environment control equipment. They can be programmed to monitor many sensor inputs and compute complex process control functions. Although many minicomputers are available, Table E-8 summarizes the characteristics of only a small subset of the standard minicomputers which have been ruggedized or militarized to withstand severe environments. Characteristics of a typical minicomputer controller are shown in Commercial Item Survey Data Sheet 14.

#### E.4 COMMAND SEQUENCING EQUIPMENT

Industrial command sequencing equipment consists of the same relay controllers, programmable solid state controllers, and minicomputers described in Section E.3.

#### E.5 DATA ACQUISITION EQUIPMENT

General data acquisition equipment consists of combinations of components, such as signal conditioning amplifiers, which process sensor outputs into a standard form; multiplexers, which sequentially or in a programmed manner sample multiple sensors for input to the data system; sample and hold circuits, which hold analog signals steady long enough for conversion to digital form; analog-to-digital converters, for input of data to digital recording units; and data recorders. Industrial data acquisition equipment is available in several forms, ranging from individual components (such as amplifiers and analog-to-digital converters) to complete systems. Commercial Item Survey Data Sheet 15 summarizes the characteristics of a typical data acquisition system.

Special data acquisition equipment consists of such special devices as the digital data magnetic tape recorders described in Commercial Item Survey Data Sheets 16 and 17, the film camera described in Commercial Item Survey Data Sheet 18, and the television camera described in Commercial Item Survey Data Sheet 19.

Table E-7  
Selected Programmable Controllers

| Manufacturer           | Model       | Program Storage Capacity and Type | Input/Output Capacity          | Input/Output Interface   | Interrupt | Emergency Routine | Maintenance and Reliability | Program Loading Compatibility       | Size (inches)                                   | Weight (pounds) | Temperature Range (centigrade degrees) |
|------------------------|-------------|-----------------------------------|--------------------------------|--|-----------|-------------------|-----------------------------|-------------------------------------|---|-----------------|--|
| Allen-Bradley          | 1760        | 1K to 1K core, 8 bit              | INPUT 16 to 96 OUTPUT 16 to 80 | 120Vac<br>24Vdc  | No        | Yes               | Plug-In Modules (eight)     | Manual or memory load with computer | 16 by 32 by 9.5                                 | 175             | 60                                     |
|                        | 1774        | 1K to 8K core, 16-bit             | 1024                           | 120Vac<br>12, 24, and 48Vdc  | No        | Yes               | Modular                     | Manual or automatic                 | 17.5 by 19.5 by 34                              | 102             | 0 to 60                                |
|                        | 1750        | PROM, 1152 or R/W core 1K         | 124                            | INPUT 120Vac 9 to 30Vdc OUTPUT 120Vac 12 to 30Vdc Computer   | No        | No                | Modular                     | Memory loader or panel              | 21 by 19 by 8 plus 8 by 8 by 9                  | 79              | 0 to 60                                |
| Digital Equipment Corp | 14130       | 8K R/W core                       | INPUT 512 OUTPUT 250           | Computer 115Vac 10 to 55Vdc  | No        | No                | Modular                     | PDP-8 with terminal                 | 22 by 17.5 by 10.75                             |                 | 0 to 65                                |
| Fx Systems             | M-G Mark I  | 4K to 32K 18-bit RAM core         | INPUT OR OUTPUT 512 total      | INPUT 12 to 115Vac 12 to 50Vdc OUTPUT 20 to 115Vac 20 to 50Vdc   | Yes       | Yes               | Modular                     | Program panel                       | 19-in. relay rack 21 in. deep 35 to 12 in. high | 137 to 262      | 0 to 45                                |
|                        | Mark II     | 4K to 22K                         | 512 total                      | High-level and low-level   | Yes       | Yes               | Modular                     | Punched tape from standard keyboard | As above  |                 |  |
| Reliance               | Automate 32 | 4K-PROM                           | 768                            | Computer   | No        | Yes               | Modular                     | Manual                              |   |                 |  |
|                        | Automate 33 | 4K to 12K R/W core                | 768                            | Computer   | No        | Yes               | Modular                     | Keyboard - Verifier                 | 86 by 95 by 24                                  |                 | 0 to 45                                |
| Process Control        | 1208-I      | 4K to 32K R/W MOS 12-bit          | 3072 digital 1152 analog       | INPUT 10 to 270Vac $\pm 15$ Vdc 2, 4, and 8-bit counter analog MUX OUTPUT 36-bit latch 55Vdc 110Vac 12-bit Digital-to-Analog | Yes       | Yes               | Modular                     | Control panel and teletype          | 72 by 24 by 30                                  |                 | 0 to 50                                |

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COMMERCIAL ITEM SURVEY DATA SHEET 13

Candidate Commercial Item Description

Programmable controller for process control.

Item Name

Un-Computer Mark II.

Supplier

FX Systems Corp.  
Mt. Marion Rd.  
Sangertries, NY 12477  
Phone (914) 246-9571

Model

Mark II, Series 900.

Performance Specifications

Storage capacity: 4,096, 18-bit words in basic processor.  
Up to 28,672 18-bit words additional capacity as  
required for the application in increments of 4,096  
by addition of from one to seven memory extension  
systems.

Memory type: High-reliability, random access, coincident-current,  
magnetic core.

Program loading: Via standard ASR-33 teletype keyboard or any com-  
parable ASCII-coded device.

Program format: Analogous to relay logic (Boolean) statements.

On/off input and output signals:

Input

On/off signals: ac and/or dc.

AC range: 8 to 280 V, 50 or 60 Hz.

DC range: 4 to 70 V, positive polarity.

Output

On/off signals: ac and/or dc.

AC range: 12 to 270 V, 50 or 60 Hz, 3 A continuous duty.

DC range: 20 to 60 V, positive polarity, 0.5 to 1.0 A continuous duty.

Total of Inputs and Outputs: 16 minimum to 512 maximum, in plug-in  
module increments of eight inputs or outputs.

Digital input and output signals:

Input

Format: 18-bit parallel entry.

COMMERCIAL ITEM SURVEY DATA SHEET 13 (CONT.)

Logic levels: Range: up to 48 Vdc. DTL/TTL-compatible. Positive true.

Input capacity: Up to eight coded inputs (144 discrete inputs) without submultiplexing.

Output

Format: Nine-bit (max) parallel, maintained.

Output range: Up to 28 Vdc, 500 mA max.

Output capacity: Up to eight coded outputs (72 discrete outputs) without multiplexing.

Analog Input and Output Signals:

Input

Input voltage:  $\pm 15$  Vdc (max).

DC input impedance: 10 Kohms + 10 pF.

Conversion time: 200  $\mu$ sec (max).

Accuracy:  $\pm 0.025\%$ .

Linearity:  $\pm 0.01\%$ .

Input capacity: Up to 32 external signal sources per input, by multiplexing.

Output

Output voltage:  $\pm 10$  Vdc (max).

External load: 5 mA (max). 300  $\mu$ F (max).

DC output impedance: 0.1 ohm.

Settling time: Less than 20  $\mu$ sec with no capacitive load.

Conversion time: 25  $\mu$ sec for full-scale.

Accuracy:  $\pm 0.05\%$  F.S.

Linearity:  $\pm 0.05\%$  F.S.

Output capacity: Up to eight analog output channels without multiplexing.

Environmental Limits:

0° to 50°C operating.

-25 to 85°C storage.

10 to 90% non-condensing relative humidity.

Data Output

On/off, digital, and analog signals. (Refer to Table 3-10).

Power

800 W, 115 V nominal, 48 to 63 Hz.

Weight

Variable, depending on options.

COMMERCIAL ITEM SURVEY DATA SHEET 13 (CONT.)

Volume

Variable, depending on options.

Packaging/Mounting

Packaged in standard 19-in. rack.

Cost

Not available.

Modifications for Zero-G Space Applications

Packaging could be modified to reduce weight.

Shipping, Handling, and Storage Considerations

-25 to +85°C storage temperature.

Table E-8

## Ruggedized/Militarized Minicomputer Performance Characteristics

|                                 | Manufacturer and Model                                |                          |   |                               |
|---------------------------------|---|--------------------------|---|-------------------------------|
|                                 | CDC<br>5600 Series                                    | DEC<br>PDP 11 R20        | Rolm 1602<br>Rugged Nova<br>AN/UYK 19V              | Sanders Associates<br>MIP-16  |
| Word length (bits)              | 8 to 32 in four-bit increments                        | 16                       | 16  | 16                            |
| Maximum memory capacity (words) | Main memory<br>4 to 262K<br>Micro memory<br>512 to 8K | 32K                      | 65K   | 65K                           |
| Memory cycle time (microsec)    | Main memory<br>1.0<br>Micro memory<br>0.080           | 1.5                      | 1.0   | 1.0 core<br>0.2 semiconductor |
| Registers                       | 2   | 8                        | Four accumulators<br>Three index<br>25 microprogram | 16                            |
| Automatic interrupt             | 16, 32, 48, or 64                                     | Four, Multilevel         | Yes   | 40                            |
| CPU I/O channels                |   | Unibus                   | 61  | Unified bus                   |
| CPU cycle time (microsec)       | 0.168   | 1.2                      | 1.0   | 0.2                           |
| Addtime (microsec)              | 0.168   | 2.8                      | 1.0   | 0.2                           |
| Instructions                    |   | 400                      | 249   | 60                            |
| Power (W)                       | 430   | 500                      | 175   | 70                            |
| Weight (lb)                     | 80  | 110                      | 34  | 6                             |
| Size (in.)                      | 19 by 10.5 by 22                                      | 10.5 by 19 by 25         | 7.62 by 10.12 by 12.56                              | 6.375 by 7.625 by 2.4         |
| Operating temperature (°C)      | -5 to +75   | 0 to +55                 | -55 to +95  | -55 to +105                   |
| Operating altitude (ft)         | 10,000  | 10,000                   | 80,000  | 70,000                        |
| Vibration                       | 5g, 5 to 500 Hz                                       | 2.5g, 9 to 500 Hz        | 10g, 5 to 2000 Hz                                   | 10g, 0 to 2000 Hz             |
| Shock                           | 50g, 11 msec  | 5g, 11 msec              | 15g, 11 msec  |                               |
| Relative Humidity (%)           | 100   | 95                       | 95  |                               |
| RFI                             | MIL-STD-461<br>Class 1D                               | MIL-STD-461A<br>Class 1C | MIL-STD-461   |                               |
| Cooling                         | Air   | Air                      | Conductive to case                                  | Conductive to case            |
| Acoustic Noise                  | MIL-STD-470   |                          |   |                               |
| Power Source                    | 115V, 47 to 400 Hz                                    | 115V, 60 Hz              |   |                               |

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COMMERCIAL ITEM SURVEY DATA SHEET 14

Candidate Commercial Item Description

Minicomputer.

Item Name

Ruggednova.

Supplier

Rolm Corp.  
18922 Forge Dr.  
Cupertino, California 95014  
Phone (408) 257-6440

Model

1602 Ruggednova (AN/UYK-19V).

Performance Specifications

Word length, 16 bits.  
Maximum memory, 8 K-words in CPU chassis.  
-65 K-words maximum.  
Memory access time, 0.4  $\mu$ sec.  
Add time, 1.0  $\mu$ sec.  
Microprogrammable.  
Registers, four accumulators.  
three index.  
25 microprogram.  
Interrupts, automatic vectored and nested.  
Hardware multiply/divide.  
Instructions, 249.  
CPU I/O channels, 61.  
CPU, independent DMA operating at up to 1 MHz.  
Remote control panel, plug-in.

Environment

Case temperature, -55 to +95°C.  
Vibration, 10 g, 5 to 2,000 Hz with vibration isolators.  
2 g, hard-mounted.  
Shock, 15 g, 11 msec.  
Humidity, 95% relative.  
RFI, MIL-STD-461.

COMMERCIAL ITEM SURVEY DATA SHEET 14 (CONT.)

Data Output

Not applicable.

Power

175 W, 28 Vdc.

Weight

34 lb.

Volume

Approximately 1 cu ft.

Packaging/Mounting

One conductively cooled 12.56 in.  
ATR chassis.

Cost

Approximately \$25K.

Modification for Space Applications

Requires qualification for space environment and shuttle amendment of  
MIL-STD-461A. Modifications may not be required.

Shipping, Storing, and Handling Considerations

No special requirements.

COMMERCIAL ITEM SURVEY DATA SHEET 15

Candidate Commercial Item Description

General-purpose analog/digital data acquisition system.

Name

Data Acquisition System.

Supplier

Datel Systems, Inc.  
1020 Turnpike St.  
Canton, Mass. 02021  
Phone (617) 828-6395

Model Number

System 256.

Performance Specification and Data Output

Refer to Table E-9.

Power

115  $\pm$ 10 Vac, 47 to 63 Hz.

Weight

12 lb (typical).

Volume

3.5 in. high by 19 in. wide by 19 in. deep.

Packaging/Mounting

Standard 19 in. rack, 3.5 in. high.

Cost

Function of modules chosen.

Modifications for Space Applications

Repackage for shock and vibration environment and conductive cooling.

Shipping, Handling, and Storage Considerations

-55 to +85°C storage temperature.

Table E-9  
System 256 Specifications

| Parameter   | Analog-to-Digital Section   |
|---|---|
| Number of Multiplexer Channels<br>Single-Ended Input            | Expandable to 256 channels in 16<br>channel increments  |
| Number of Multiplexer Channels<br>Differential Input (Optional) | Expandable to 128 channels in eight-<br>channel increments  |
| Number of Simultaneous<br>Sample/Hold Channels                  | Expandable to 64 channels in two-<br>channel increments   |
| Input Voltage Ranges  | +5V FS, +10V FS, $\pm 5V$ FS, $\pm 10V$ FS  |
| Channel Input Acquisition Time                                  | 5 $\mu$ sec to $\pm 0.025\%$ of FS  |
| Channel Input Impedance   | 100 Megohms "on" or "off"   |
| Input Configuration   | Single-ended or Differential  |
| Maximum Input Overload  | $\pm 15V$   |
| Input Channel Time Skew   | 50 nsec   |
| Simultaneous S/H Section  |   |
| Maximum Common Mode<br>Voltage - (3)                            | Any combination of<br>20V peak-to-peak - $E_s + ECM$  |
| Common Mode Input<br>Impedance - (3)                            | >100 Megohms  |
| Common Mode Source<br>Impedance - (3)                           | 1 Kohm unbalanced   |
| Common Mode Rejection<br>Ratio - (3)                            | 60 dB at 1 KHz<br>80 dB at 60 Hz  |
| Crosstalk (Between inputs)                                      | 80 dB at 100 Hz<br>45 dB at 10 MHz  |
| Output Resolution   | 8, 10, 12, and 14 binary bits   |
| Output Data Coding (4)  | Straight Binary - unipolar input<br>Offset Binary - bipolar input<br>2's Complement - bipolar input   |
| Throughput Rate   | 8 Binary Bits - 100 KHz<br>10 Binary Bits - 50 KHz<br>10 Binary Bits - 100 KHz (opt.)<br>12 Binary Bits - 50 KHz<br>14 Binary Bits - 20 KHz |
| Aperture Time   | 50 nsec   |



Table E-9 (Cont.)

| Parameter                        | Analog-to-Digital Section  |
|----------------------------------|--|
| Accuracy                         | $\pm 0.02\%$ of FS $\pm 1/2$ LSB   |
| Temperature Coefficient          | 40 ppm per $^{\circ}\text{C}$  |
| Throughput Rate                  | up to 100 KHz  |
| Linearity                        | $\pm 1/2$ LSB  |
| Device Select                    | 1 line, 1 TTL Load-Negative True   |
| Random/Sequential                | 1 line, 1 TTL Load-Negative True (seq.)  |
| Reset                            | 1 line, 1 TTL Load-Negative True   |
| Strobe                           | 1 line, 1 TTL Load-Negative True   |
| Convert Command Input            | 1 line, 1 TTL Load-Negative True   |
| Random Address Inputs            | 9 lines, 1 TTL Load-Negative True  |
| Analog-to-Digital Converter Data | Up to 14 parallel lines-TTL Compatible (1)   |
| Serial Output Train              | 1 line-TTL Compatible (1)  |
| Busy (E.O.C.)                    | 1 line-TTL Compatible (1)  |
| Frame Sync                       | 1 line-TTL Compatible (1)  |
| Analog-to-Digital Clock          | 1 line-TTL Compatible (1)  |
| Input Strobe Output              | 1 line-TTL Compatible (1)  |
| Output Strobe Output             | 1 line-TTL Compatible (1)  |
| Buffer Full Output               | 1 line-TTL Compatible (1)  |
| Output Data Display              | Up to 14 Bits of Analog-to-Digital Read Out  |
| Channel Address Switches         | Address Multiplexer in Random Mode   |
| Channel Address Lamps            | Display Multiplexer Position   |
| Analog-to-Digital Mode Switch    | Selects Analog-to-Digital Operation  |
| Analog-to-Digital Convert Switch | Will initiate an Analog-to-Digital Conversion  |
| Reset Switch                     | Resets Multiplexer to Channel One  |
| Random/Sequential Switch         | Selects Multiplexer Mode of Operation  |
| Advance Switch                   | Random Mode-Will Select Addressed Channel<br>Sequential Mode-Will Advance to Next Higher Channel |
| Local/Remote Switch              | Selects Source of System Control, Front Panel Controls or Computer                               |

Table E-9 (Cont.)

| Parameter   | Analog-to-Digital Section   |
|---|---|
| Last Channel Selector                                 | Short Cycle Multiplexer in Sequential Mode  |
| Power ON/OFF Switch                                   | Applies AC Power to System  |
| Operating Temperature Range                           | 0 to +70°C  |
| Storage Temperature Range                             | -55 to 85°C   |
| Relative Humidity                                     | Up to 100% Non-condensing   |
| Physical Size   | 3.5 in. high by 19 in. wide by 19 in. deep  |
| Weight  | 12 lb (Typical)   |
| I/O Mating Connectors                                 | Up to 11<br>Viking #3VH25/1JN5  |
| Input Power   | 115 ± 10 Vac at 47 to 63 Hz<br>225 ± 15 Vac at 50 to 400 Hz (opt.)                        |
| (1) Open Collector. Will Sink 30 mA.<br>(2) Optional. | (3) Pertains only to Differential Input.<br>(4) Contact Factory for Binary-Coded Decimal. |

| Parameter                        | Digital-to-Analog Section   |
|----------------------------------|---|
| Number of Channels               | Expandable to 32 channels in one-channel increments   |
| Resolution<br>Digital Coding (3) | 8, 10, 12 Binary Bits<br>Straight Binary<br>Offset Binary<br>Two's Complement                             |
| Data Inputs                      | DTL or TTL compatible.<br>Negative True Logic.<br>Loading: one TTL Load.                                  |
| Data Strobe                      | Information must be present at the register inputs of the DAC prior to strobing.<br>Loading: one TTL Load |
| Update Rate                      | 500 KHz   |

Table E-9 (Cont.)

| Parameter                       | Digital-to-Analog Section                                  |
|---------------------------------|--|
| Number of Analog Outputs        | up to 32 channels  |
| Accuracy                        | $\pm 0.01\%$ of FS $\pm 1/2$ LSB                           |
| Output Voltage Range (2)        | 0 to 10V FS<br>0 to 5V FS<br>$\pm 10$ V FS<br>$\pm 5$ V FS |
| Output Current                  | $\pm 10$ ma (typical)                                      |
| Output Loading                  | 1 Kohm for + 10 V Output<br>500 ohms for +5 V Output       |
| Output Settling Time            | 2 $\mu$ sec to $\pm 0.025\%$ of FS                         |
| Resolution                      | $\pm 1$ LSB  |
| Linearity                       | $\pm 1/2$ LSB  |
| Temperature Coefficient         | $\pm 20$ ppm per $^{\circ}$ C of FS                        |
| Long Term Stability             | $\pm 0.01\%$ per six-month period                          |
| Reference Source                | Internal   |
| Device Select                   | 1 line, 1 TTL Load-Negative True                           |
| Random/Sequential               | 1 line, 1 TTL Load-Negative True (seq.)                    |
| Reset                           | 1 line, 1 TTL Load-Negative True                           |
| Strobe                          | 1 line, 1 TTL Load-Negative True                           |
| Convert Command Input           | 1 line, 1 TTL Load-Negative True                           |
| Random Address Inputs           | 9 lines, 1 TTL Load-Negative True                          |
| Input Strobe Output             | 1 line, TTL Comp. (1)                                      |
| Input Data Switches             | Allows Manual Loading of Data Into Each Digital-to-Analog  |
| Channel Address Switches        | Address Digital-to-Analog in Random Mode                   |
| Channel Address Lamps           | Display Digital-to-Analog Channel Position                 |
| Digital-to-Analog Mode Switch   | Selects Digital-to-Analog Operation                        |
| Digital-to-Analog Strobe Switch | Will Initiate a Digital-to-Analog Conversion               |
| Reset Switch                    | Resets Digital-to-Analog to Channel One                    |

Table E-9 (Cont.)

| Parameter   | Digital-to-Analog Section   |
|---|---|
| Random/Sequential Switch<br>Advance Switch  | Selects Mode of Operation<br>Random Mode-Will Select Addressed Channel<br>Sequential Mode-Will Advance to Next Higher Channel |
| Local/Remote Switch   | Selects Source of System Control.<br>Front Panel Controls or Computer.  |
| Last Channel Selector   | Short Cycle Digital-to-Analog Channels in Sequential Mode   |
| Power On/Off Switch   | Applies AC Power to System  |
| Operating Temperature Range   | 0 to + 70°C   |
| Storage Temperature Range   | -55 to + 85°C   |
| Relative Humidity   | Up to 100% Non-condensing   |
| Physical Size   | 3.5 in. high by 19 in. wide by 19 in. deep  |
| Weight  | 12 lb (Typical)   |
| I/O Mating Connectors   | Viking #3VH25/1JN5  |
| Input Power   | 115 ± 10 Vac at 47 to 63 Hz<br>225 ± 15 Vac at 47 to 63 Hz (opt.)   |
| (1) Open Collector. Will Sink 30 mA.<br>(2) Fast Settling Current Output Available on Special Order.<br>(3) Contact Factory for Binary-Coded Decimal. |   |

COMMERCIAL ITEM SURVEY DATA SHEET 16

Candidate Commercial Item Description

Digital tape recorder.

Supplier

Odetics, Inc.  
1859 South Manchester  
Anaheim, California 92802  
Telephone (714) 750-2111

Model Number

DDS-3100.

Performance Specifications

Input data rate, 32/512/1,024 kbps.  
Input data format, NRZ-L (plus clock).  
Record time, 800, 50, and 25 min.  
Total storage,  $1.53 \times 10^9$  bits.  
Record/reproduce ratio, 32:1, 2:1, and 1:1.  
Reproduce time, 25 min.  
Reproduce rate, 1,024 kbps NRZ-L.  
Random error rate, 1 in  $10^6$ .  
Jitter/output data stability,  $\pm 0.1\%$ .  
Tape length, 1,800 ft.  
Tape width, 0.25 in.  
Tape thickness, 1.0 mil.  
Record speed, 2.25, 36, and 72 ips.  
Packing density, 14.2 kbits per in.  
Reproduce speed, 72 ips.

Environments

Vibration, 185 g rms, 20 to 2,000 cycles (three axes).  
Shock, 100 g, 0.5 msec half sine (three axes).  
Thermal vacuum,  $10^{-6}$  Torr (0 to 120°F).  
Linear accelerator,  $\pm 15$  g for 5 min (three axes).  
EMI, MIL-STD-461A

Data Output

See performance specifications.

COMMERCIAL ITEM SURVEY DATA SHEET 16 (CONT.)

Power

Operating voltage, 24 to 32 Vdc.  
Record power, 14, 17, and 22 W.  
Reproduce power, 30 W.

Weight

16.8 lb.

Volume

9 by 12 by 6 in.

Packaging/Mounting

Rack or base mount.

Cost

Approximately \$80K.

Modification for Space Application

None.

Shipping, Storage, and Handling Considerations

None.

COMMERCIAL ITEM SURVEY DATA SHEET 17

Candidate Commercial Item Description

Digital magnetic tape recorder.

Item Name

Fighter Aircraft Digital Data Tape Recorder.

Supplier

Emerson Electric Co.  
Industrial Controls Div.  
3300 S. Standard St.  
P.O. Box 1679  
Santa Ana, Calif. 92702  
Phone (714) 545-5581

Model Number

Model R-215-8008/ALQ-125 (V).

Performance Specifications

Record format: IBM computer compatible, 800 bpi, 9-track.  
Tape capacity: 2,400 ft, 0.5 in. Mylar tape on 10.5 in. reel.  
Tape speeds: 3.75 ips record and reproduce.  
60 ips fast forward and rewind.  
Data rate: 3,000 bytes per sec at 3.75 ips.  
Bit dropout:  $2 \times 10^5$  max.  
Remote controls: Start, stop, record, rewind, and fast forward.  
Environment: (Operational)  
Temperature: -62 to +90°C non-operating.  
-40 to +72°C operating.  
Vibration: MIL-E-5400M.  
Explosion: MIL-STD-810B, Method 511, Proc 1.  
Humidity: MIL-STD-810B, Method 507.  
Shock: MIL-STD-810B, Method 516.1, Proc 1.  
Salt fog: MIL-STD-810B, Method 509, Proc 1.  
Fungus: MIL-STD-810B, Method 508, Proc 1.  
Acoustic noise: MIL-STD-810B, Method 515, Proc 1, Cat 8.  
Sand and dust: MIL-STD-810B, Method 510, Proc 1.  
EMI: MIL-STD-461.  
Size: 15 by 11.5 by 5 in.

Data Output

See specifications above.

COMMERCIAL ITEM SURVEY DATA SHEET 17 (CONT.)

Power

155 W, 115  $\pm$ 5 Vac, 400 Hz, three-phase.

Weight

35 lb.

Volume

Approximately 1 cu ft.

Packaging/Mounting

Aluminum case.

Modification for Space Application

Mount in pressurized case and modify for conductive cooling.

Shipping, Storing, and Handling Considerations

See environmental data above.



COMMERCIAL ITEM SURVEY DATA SHEET 18

Candidate Commercial Item Description

Documentation camera for recording process observations.

Item Name

Magazine loading camera.

Supplier

Instrumentation Marketing Corp.  
820 S. Mariposa St.  
Burbank, California 91506  
Phone (213) 849-6251

Model Number

16 mm-1 VN-100.

Performance Specifications

Frame rate: Pulse up to 12 pps, cine rates of 16, 24, 48, 64, and 100 fps.  
Aperture size: 0.296 by 0.552 in.  
Film capacity: 65 and 100 ft magazines.  
Lens mount: "C" (USA PH 22.76).  
Auto exposure control:  
    Light range: 4.25 to 17,376 foot-lamberts.  
    ASA calibration: 10 to 2360.  
Operating temperature: -20 to +150°F.

Data Output

Film.

Power

Motor: 28 Vdc, 2 A max.  
Heater: 28 Vdc, 100 W.

Weight

3.5 lb with film.

Volume

Approximately 10 by 3 by 2.5 in.

Packaging/Mounting

See Figure E-4.

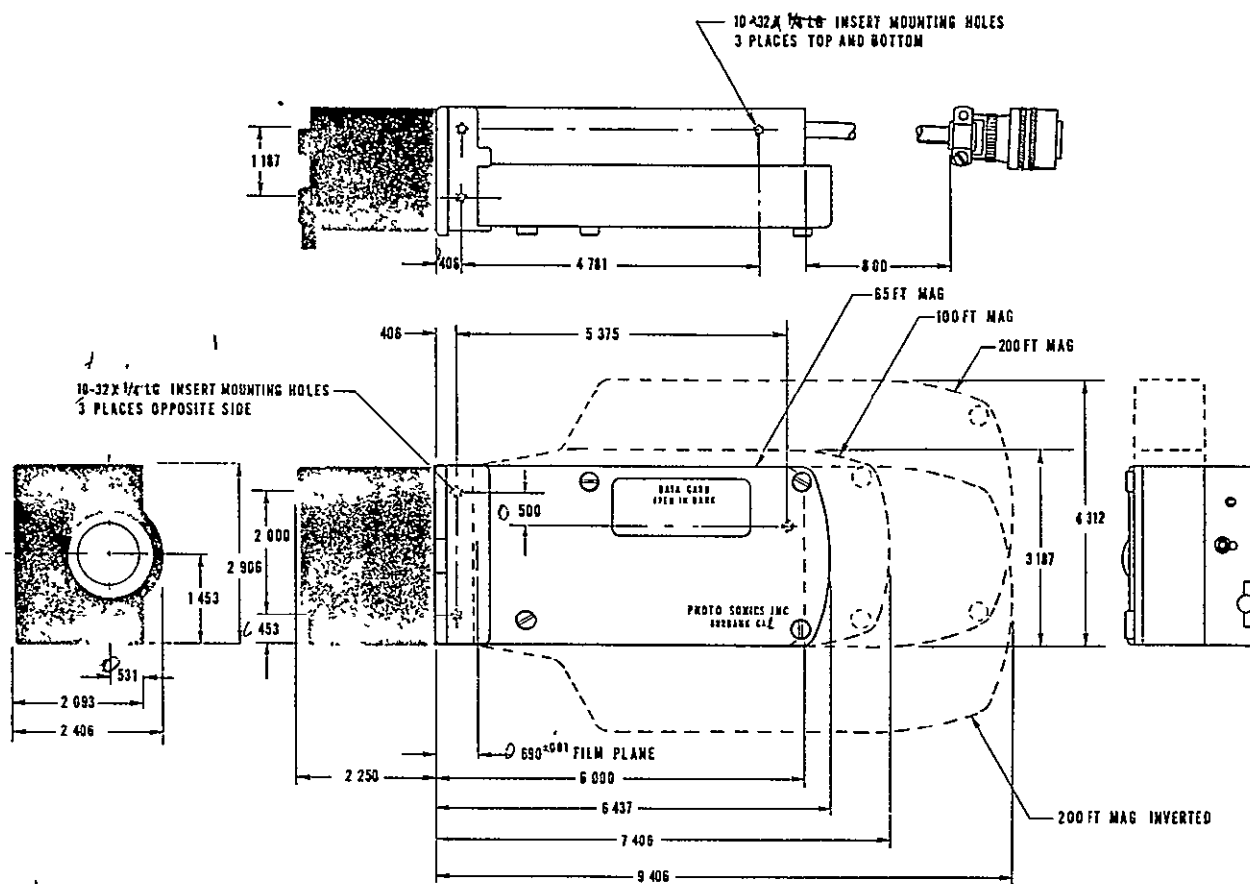
## COMMERCIAL ITEM SURVEY DATA SHEET 18 (CONT.)

## Modification for Space Application

Package in sealed controlled atmosphere container; provide conductive cooling.

## Shipping, Storing, and Handling Considerations

No special requirements.



Note: Shaded area indicates optional Apex Automatic Exposure Control

All dimensions are in inches unless otherwise indicated,  
Specifications subject to change without notice.

Figure E-4 Documentation Camera Package and Mounting

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COMMERCIAL ITEM SURVEY DATA SHEET 19

Candidate Commercial Item Description

Solid state imaging system.

Item Name

Charge Injection Device Imaging System.

Supplier

General Electric Co.  
Optoelectronic Systems Operation  
Building 3, Electronics Park  
Syracuse, N.Y. 13201  
Phone (315) 456-2832

Performance Specifications

Operating conditions

100 by 100 imager.

60 cycle field rate.

Output signals

Preamplifier video: 0.5 V peak-to-peak (1,000-ohm load).

Horizontal drive:  $3.5 \pm 0.5$  V peak-to-peak (75-ohm load).

Vertical Drive:  $3.5 \pm 0.5$  V peak-to-peak encoded signal.

Dynamic range: 500 to 1.

E.6 PROCESS CONTROL ACTUATOR EQUIPMENT

Industrial control actuator equipment in the form of relays, valves, motors, and similar end-control elements are widely available. These elements are so readily available and so dependent on the process system that no attempt is made to describe them in detail in this report. Reference is made to the abundant catalog data readily available for these details.